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Quartz Hill Molybdenum Project Mine Development

Final Environmental Impact Statement

Appendices

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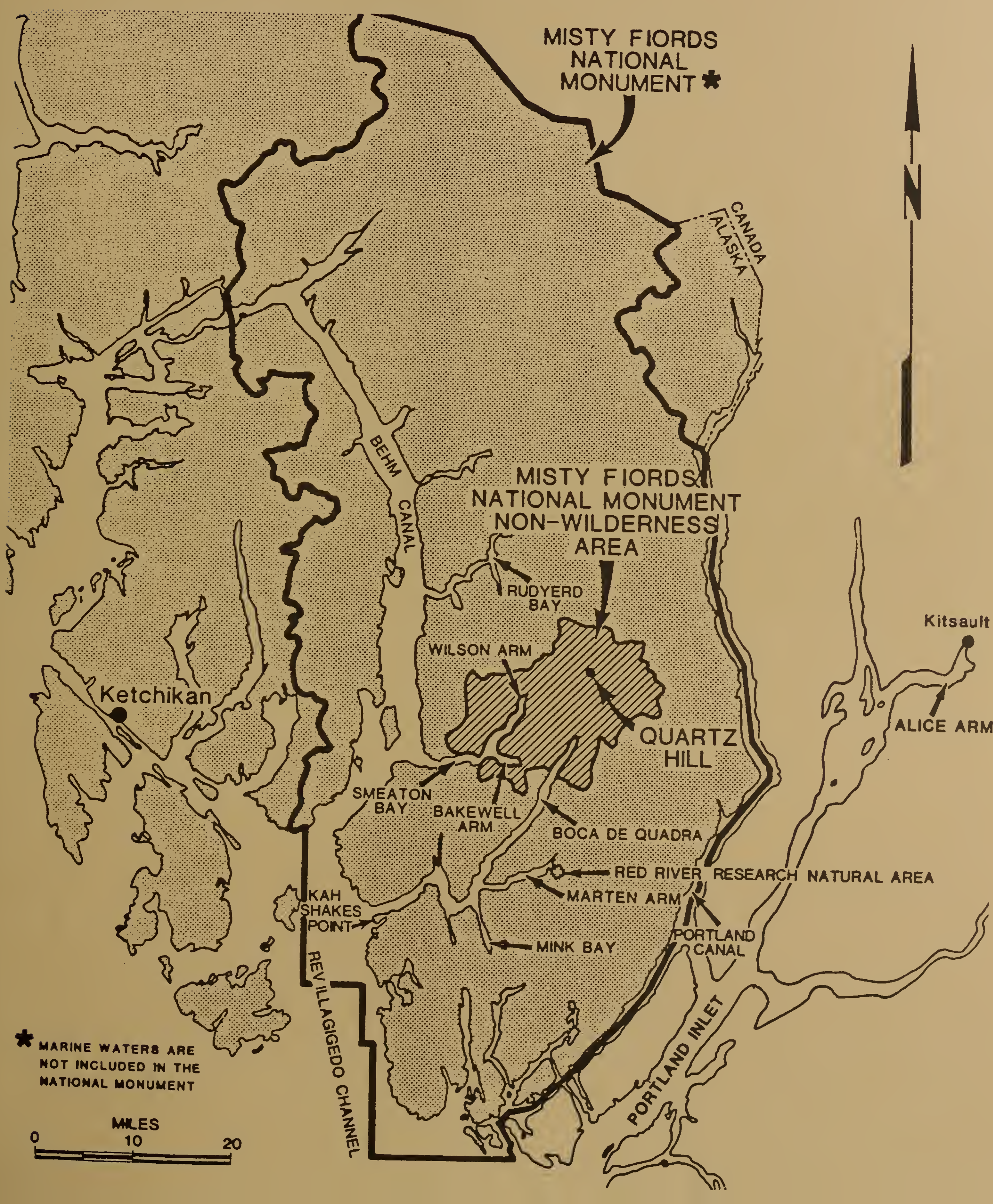
QUARTZ HILL MOLYBDENUM MINE DEVELOPMENT FINAL ENVIRONMENTAL IMPACT STATEMENT

LIST OF APPENDICES

APPENDIX A

DESCRIPTION OF THE PROPOSED PROJECT & ALTERNATIVE CONCEPTS



APPENDIX A

DESCRIPTION OF PROPOSED PROJECT
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I. INTRODUCTION

United States Borax & Chemical Corporation (U.S. Borax) initiated a geochemical exploration program in Tongass National Forest in southeastern Alaska that resulted in the discovery in 1974 of a significant molybdenum deposit (Figures I-1 and I-2). This discovery led to the acquisition of rights to this mineral deposit by the location of mining claims under the federal mining laws as shown in Figure I-3. This mineral deposit and area has been designated as Quartz Hill. Subsequent exploration and development has shown the Quartz Hill molybdenum deposit to be one of the largest in the world, and U.S. Borax, acting on behalf of the owner of the Quartz Hill property, Pacific Coast Molybdenum Company, has formulated plans to develop a world-class molybdenum mine at the site. This appendix describes U.S. Borax's proposed development concept and several alternative development concepts that are analyzed in detail in the EIS. Figure I-4 presents a general map of the project area showing names of important geographical locations that are used throughout this report.

Since the Quartz Hill molybdenum deposit is located in a remote, undeveloped area of southeastern Alaska, project development must include not only the mining and milling facilities needed to extract and process the ore, but also a full range of support facilities including: a power plant and distribution system to supply project electrical needs; employee housing; land and marine transportation facilities such as roads, wharves, barges, etc.; a mine, process, and potable water supply; water and wastewater treatment facilities; and shops, warehouses, offices, laboratories, and communications/ navigational facilities. This appendix describes a range of project "concepts" including the proposed project and several reasonable alternatives that are analyzed in detail in the EIS. Each of these project "concepts" consists of several project "components" including the mine site facilities, crusher, ore transport, mill, tailings transport and disposal, employee housing, power plant, and ancillary facilities needed to develop a complete project. Each of the project "components" comprising the project "concepts" is described. Descriptions are provided for both alternative components and those that have been eliminated from detailed consideration because of engineering, economic, and environmental factors.

Section II describes the proposed project, including tailings disposal in Wilson Arm. Other viable project components have been combined into several alternative concepts which are described in Section III.

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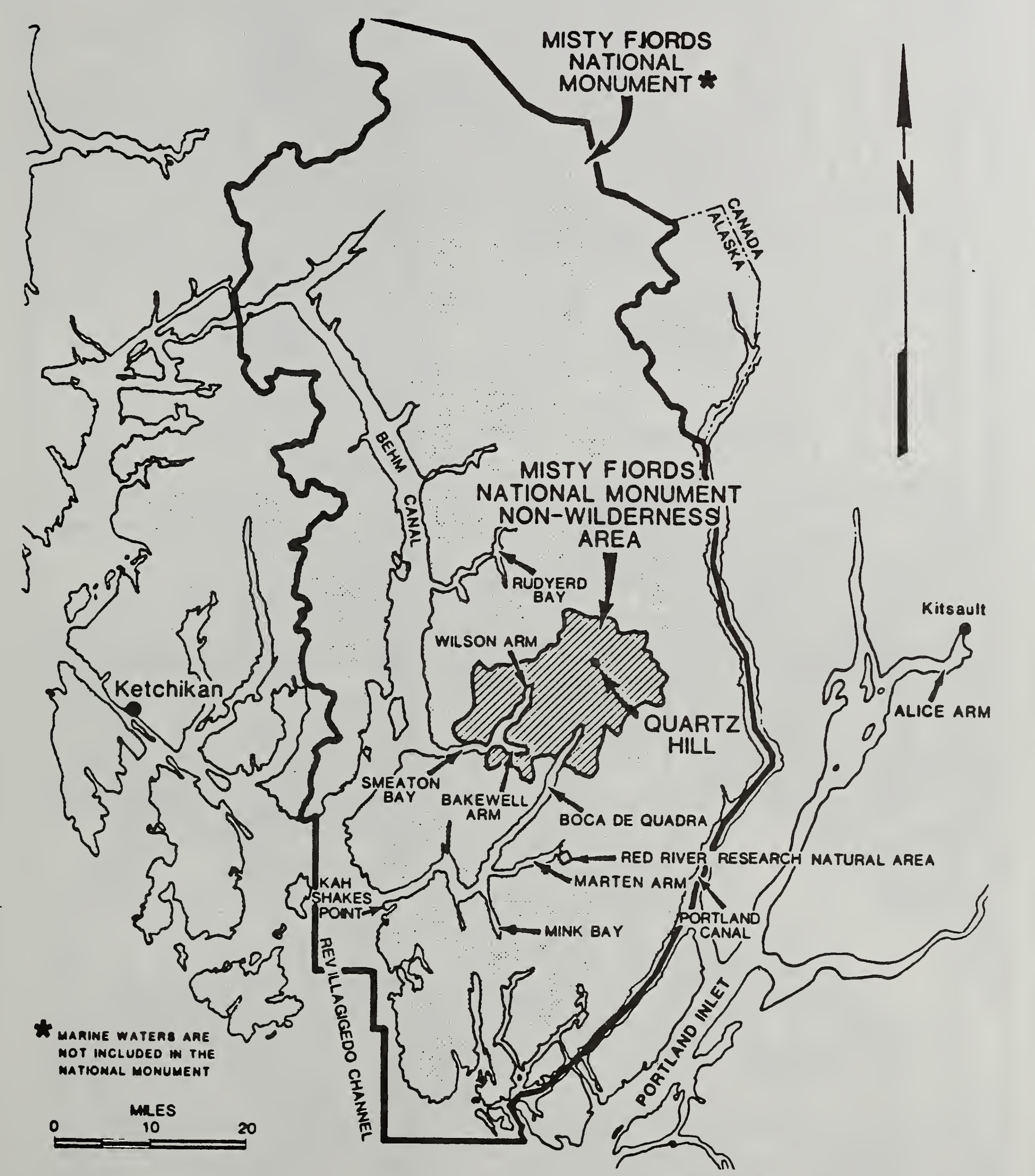
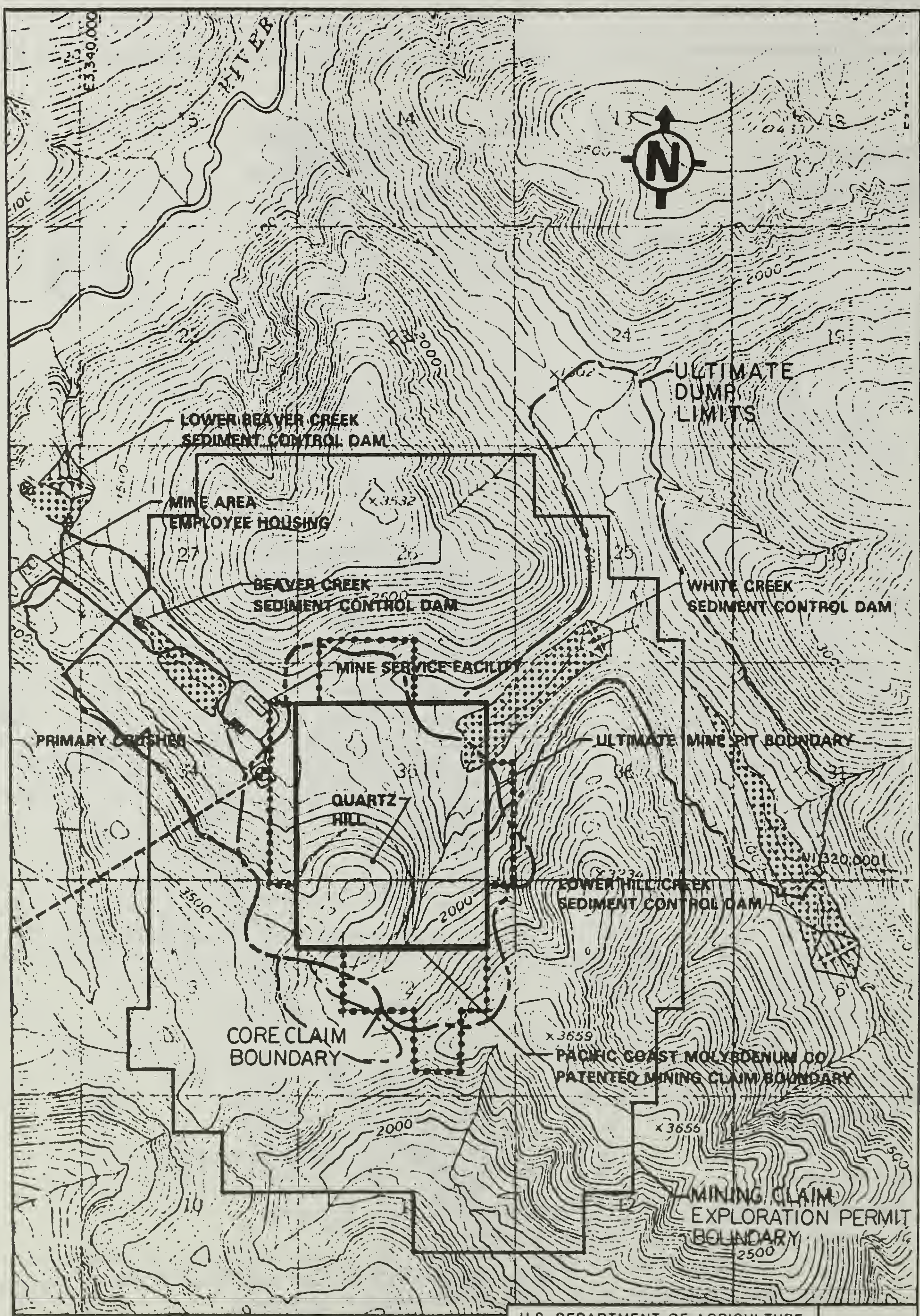
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE QUARTZ HILL MOLYBDENUM PROJECT MINE DEVELOPMENT EIS	FIGURE I-1 envirosphere company A Division of EBASCO SERVICES INCORPORATED
REGIONAL LOCATION MAP	
SOURCE U.S. BORAX DATE FEB 84	



U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE QUARTZ HILL MOLYBDENUM PROJECT MINE DEVELOPMENT EIS	FIGURE I-2 envirosphere company A Division of EBASCO SERVICES INCORPORATED
GENERAL PROJECT LOCATION	
SOURCE U.S. FOREST SERVICE DATE NOV 83	



0 1/4 1/2 1

SCALE - MILES

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

MINING CLAIM BOUNDARIES

SOURCE U.S. BORAX DWG. 8K-M-260 DATE MAR 84

FIGURE
I-3

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QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

QUARTZ HILL PROJECT AREA
IMPORTANT GEOGRAPHICAL LOCATIONS

FIGURE I-4

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SOURCE ENVIROSPHERE CO. DATE NOV 83

II. TUNNEL CREEK MILL WITH WILSON ARM TAILINGS DISPOSAL AND COMMUTE OPTION ALTERNATIVE

A. MINE SITE

The locations of the project facilities for this alternative are shown in Figure II-1. The project development schedule is presented in Figure II-2.

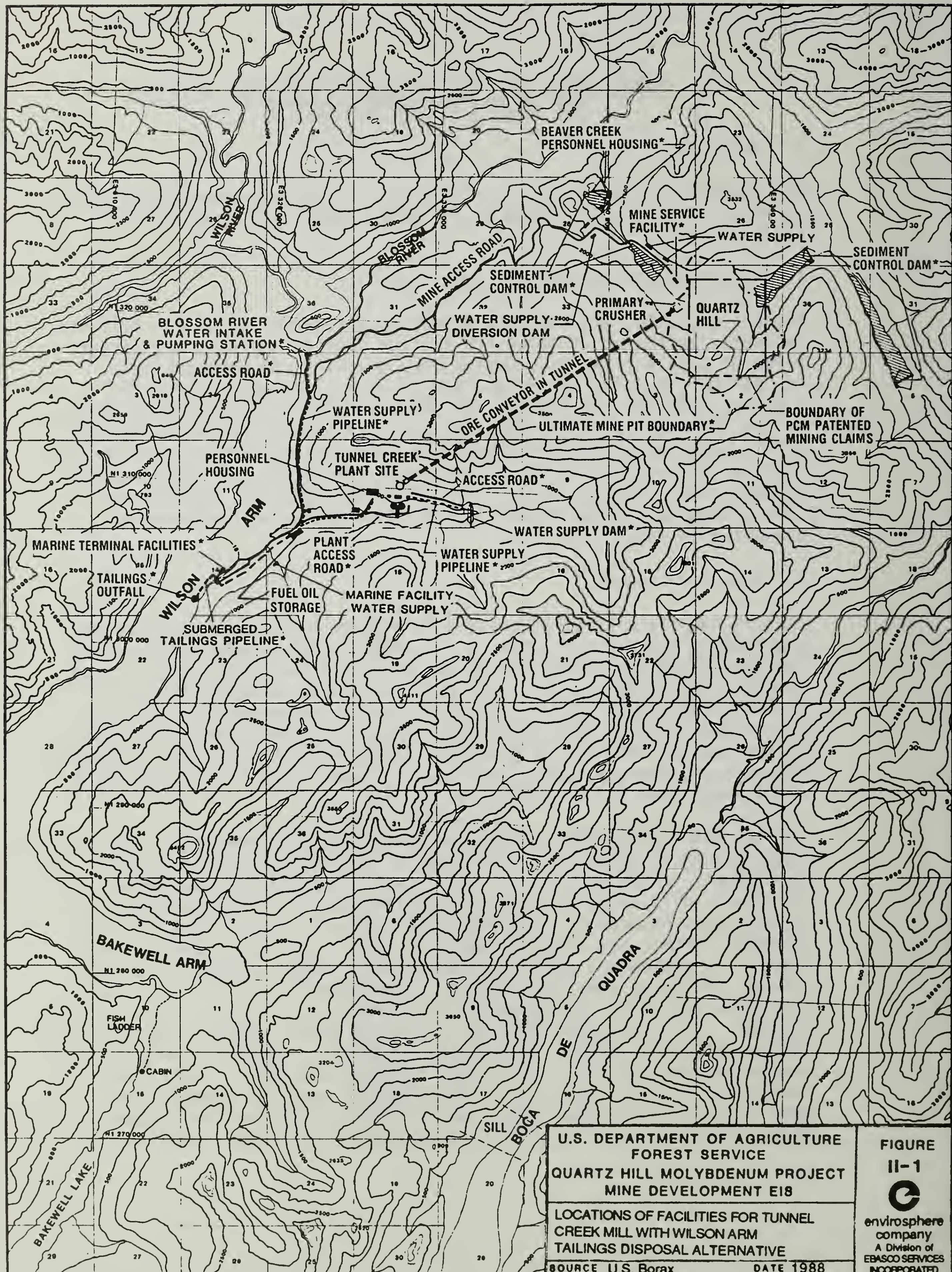
1. Description of Ore Body and Reserves

Proven, probable, and possible minable ore reserves at Quartz Hill are currently estimated at about 1.5 billion tons of ore with an average grade of 0.14 percent MoS_2 (molybdenum disulfide or molybdenite). The northern portion of the ore body, lying at surface elevations of 1,800 to 1,900 ft, is referred to as Bear Meadow. The southern portion of the ore body lying at elevation 2,700 ft is referred to as Quartz Hill. Based on mining and processing approximately 80,000 tons per day (tpd) at an average of 0.14 percent MoS_2, the Quartz Hill mine would produce about 1.1 million tons of molybdenum (Mo) over its 55 year life. Chemical and mineralogical characteristics of the ore are presented in Table II-1.

2. Mine Development

The ore body is a large porphyry-type deposit lying near the surface and minable by open pit methods. In general, this technique involves the extracting and processing of ore and waste materials from a large generally circular or elliptical pit. Mining is controlled by the distribution of ore grades, but is generally accompanied by a successive widening and deepening of the pit. The maximum dimensions of the open pit would be 2.0 miles (mi) long and 1.3 mi wide, and would occupy approximately 1,040 acres (ac) (Figure II-1). The final depth would range from 1,325 to 1,875 ft.

Initial mine development during the preproduction phase would involve construction of access roads and removal of the overlying rock prior to development of the open pit. Waste materials including overburden, rock, and soils would be removed from the pit and placed beyond the ultimate pit boundaries. Merchantable timber would be identified and harvested within the planned limits of the pit and preproduction waste dumps. In subsequent years similar harvests would be made in advance of mine and waste dump development. Noncommercial timber in the waste rock areas would be left standing and buried as the waste dump expands. Prior to actual mining, the areas within the pit limits would be cleared and grubbed. Noncommercial timber in the pit area would be removed as part of the clearing and grubbing operation. All slash, underbrush, stumps, and other organic debris would be removed and, where appropriate, selectively used as erosion barriers or mulches. Excess material would be placed in the waste rock dump. Merchantable


BEAVER CREEK PERSONNEL HOUSING*
MINE SERVICE FACILITY*
WATER SUPPLY
SEDIMENT CONTROL DAM*
WILSON RIVER
BLOSSOM RIVER
MINE ACCESS ROAD
SEDIMENT CONTROL DAM*
PRIMARY CRUSHER
QUARTZ HILL
WATER SUPPLY DIVERSION DAM
BLOSSOM RIVER WATER INTAKE & PUMPING STATION*
ACCESS ROAD*
ORE CONVEYOR IN TUNNEL
WATER SUPPLY PIPELINE*
ULTIMATE MINE PIT BOUNDARY*
BOUNDARY OF PCM PATENTED MINING CLAIMS
PERSONNEL HOUSING
TUNNEL CREEK PLANT SITE
ACCESS ROAD*
WATER SUPPLY DAM*
MARINE TERMINAL FACILITIES*
PLANT ACCESS ROAD*
WATER SUPPLY PIPELINE*
TAILINGS* OUTFALL
FUEL OIL STORAGE
MARINE FACILITY WATER SUPPLY
WILSON ARM
SUBMERGED TAILINGS PIPELINE*
BAKEWELL ARM
FISH LADDER
CABIN
BAKEWELL LAKE
SILL
BOCA DE QUADRA
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
LOCATIONS OF FACILITIES FOR TUNNEL CREEK MILL WITH WILSON ARM TAILINGS DISPOSAL ALTERNATIVE
SOURCE U.S. Borax
DATE 1988
FIGURE II-1
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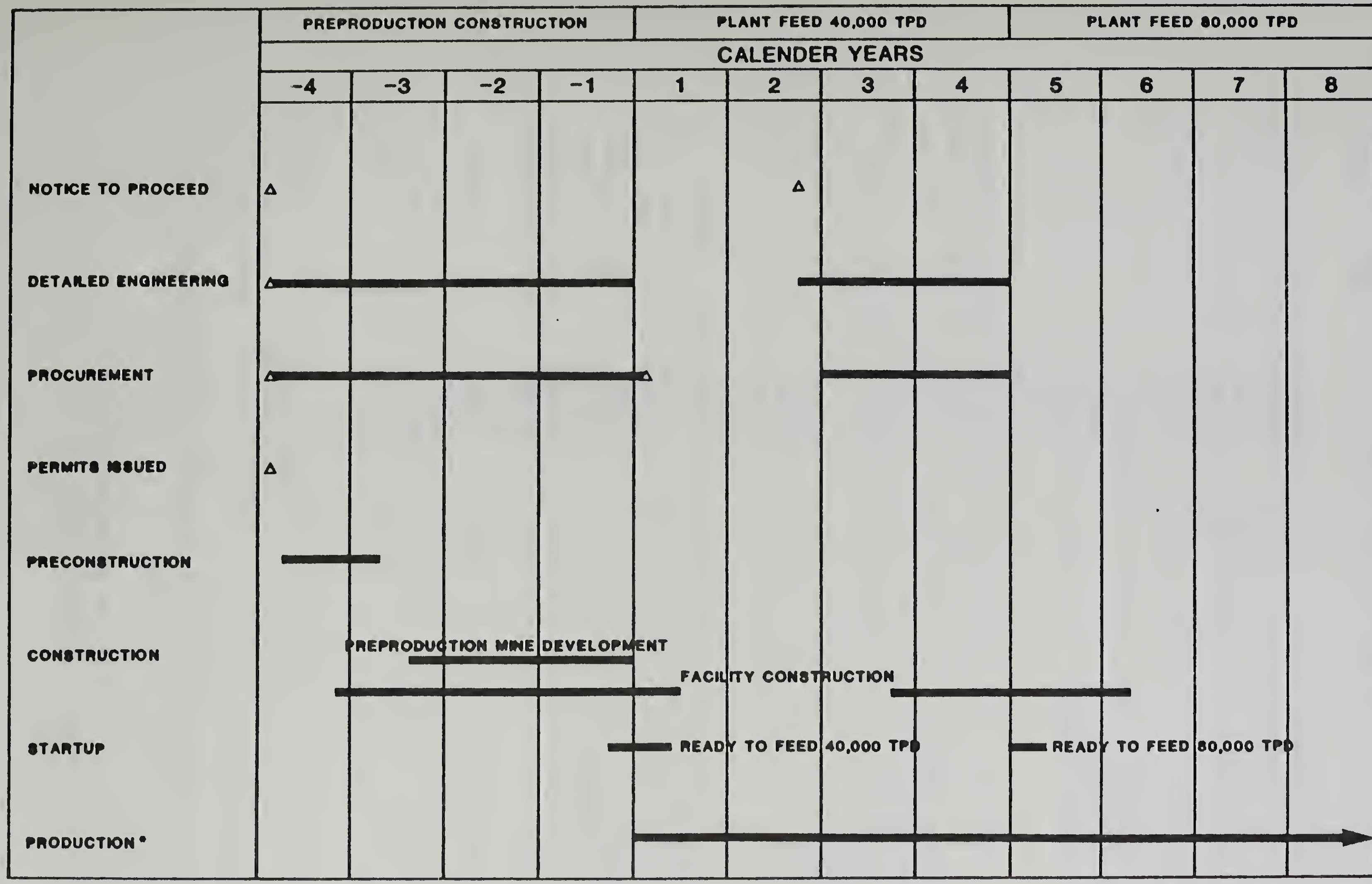

*Nominal 40,000 tons per day expanding to nominal 80,000 tons per day in 4 to 6 years. Production rates appearing throughout this report are described as "nominal". A nominal rate is the material throughput, averaged over a year, for which the plant is designed. However, after plant operation has been optimized, actual daily production rates typically vary above and below the nominal rate by 10 to 15 percent.

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MINE DEVELOPMENT EIS

TENTATIVE PROJECT DEVELOPMENT SCHEDULE

SOURCE U.S. BORAX DATE FEB 1984

FIGURE II-2

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TABLE II-1

ORE CHARACTERIZATION

Component	Weight Percent 1/
Chemical Balance	
Silicon dioxide (SiO_2)	76.92
Aluminum oxide (Al_2O_3)	11.6
Iron (total) (Fe)	1.69
Magnesium oxide (MgO)	0.96
Calcium oxide (CaO)	0.90
Sodium oxide (Na_2O)	3.15
Potassium oxide (K_2O)	4.56
Molybdenum (total) (Mo)	0.217
Molybdenum (oxides) (MoO_x)	0.001
Copper (Cu)	0.009
Lead (Pb)	0.006
Zinc (Zn)	0.004
Sulfur (S)	0.63
Zirconium dioxide (ZrO_2)	0.01
Carbon dioxide (CO_2)	0.52
	101.18
Mineral Balance	
Quartz	39.99
Feldspar (total)	52.62
Biotite	2.51
Chlorite	2.51
Amphibole	0.56
Molybdenite (MoS_2)	0.362
Molybdite	0.001
Pyrite 2/ (FeS_2)	0.88
Chalcopyrite ($CuFeS_2$)	0.026
Galena	0.007
Sphalerite (ZnS)	0.006
Magnetite 3/	0.91
Calcite	1.18
Zircon	0.02
Garnet 4/	Tr.
Apatite 4/	Tr.
Sphene 4/	Tr.
Rutile 4/	Tr.
Ilmenite 4/	Tr.
	101.57 5/

1/ These data are from the mini pilot plant circuit 6/23/83.
2/ Includes minor pyrrhotite (Fe_7S_8).
3/ Include hematite.
4/ Trace minerals not included in balance calculation.
5/ Balance has 0.44 percent excess Al_2O_3.
Source: U.S. Borax 1983b.

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timber outside of the valid mining claim boundaries would be harvested in accordance with terms specified in the Forest Service Special Use Permit for mine development. Overburden, including muskeg, unconsolidated alluvium, and glacial till, would be stripped from the area in advance of pit development and ore extraction.

The preproduction phase (Figure II-3) is expected to last up to 36 months, and involves excavation of the shop and crusher site, access roads, and shovel sites. Between 2.5 and 4.0 million tons of material would be removed from the pit for use as construction fill and to develop shovel production sites. Where practical, any ore encountered during this phase would be stockpiled in place, or may be stockpiled near the crusher. Overburden, trees, and brush would be removed from the various facility sites and in the initial mining area, and removal would continue in a timely manner to clear subsequent mining areas.

Overburden, including muskeg and glacial till, would be removed by relatively small, versatile equipment that can handle this material more selectively than the large capacity mining equipment which would be mobilized later. In areas where only a thin layer of glacial till exists, it is likely that muskeg and glacial till would be mixed and removed together. This mixed glacial till and muskeg would be disposed of with other waste rock. In areas where glacial till is deep, muskeg and glacial till would be separated to facilitate the most beneficial handling method for each material. The muskeg would be disposed of in the waste rock disposal areas. The glacial till would be stockpiled for future use as topsoil. Complete separation would not be necessary, as a small amount of muskeg mixed with the glacial till would improve its topsoil qualities. Storage areas would be located on both sides of the open pit to minimize haul distances for the material when it is used as topsoil. Since there is more glacial till than would be required for reclamation, any material in excess of that needed for topsoil would be placed in the waste rock disposal areas. Removal of overburden would be nearly completed within the first 6 years of mining.

A muskeg layer of 0 to 5 ft thickness would be removed from the Bear Meadow pit, construction sites, and sedimentation dam site areas. During the preproduction phase approximately 8.6 million cubic feet (mcf) of muskeg would be removed. During the first 5 years of mining approximately 5.7 mcf of additional muskeg would be removed.

Glacial till would be removed with muskeg and if separable would be stockpiled for use as topsoil. Any excess glacial till would be used as aggregate in road and pad construction, stockpiled for use in dam construction, or deposited on overburden dumps. If the till is not separable it would be disposed of with the muskeg. Approximately 20 mcf of glacial till would be removed during the preproduction phase. Glacial till thicknesses of 4-8 ft are projected during the mine's first 3 years of operation, but would increase to as much as 37 ft in east Bear Meadow during the fifth year. An additional 76 mcf of glacial till would be stripped from the pit area in the first 6 years of mining.

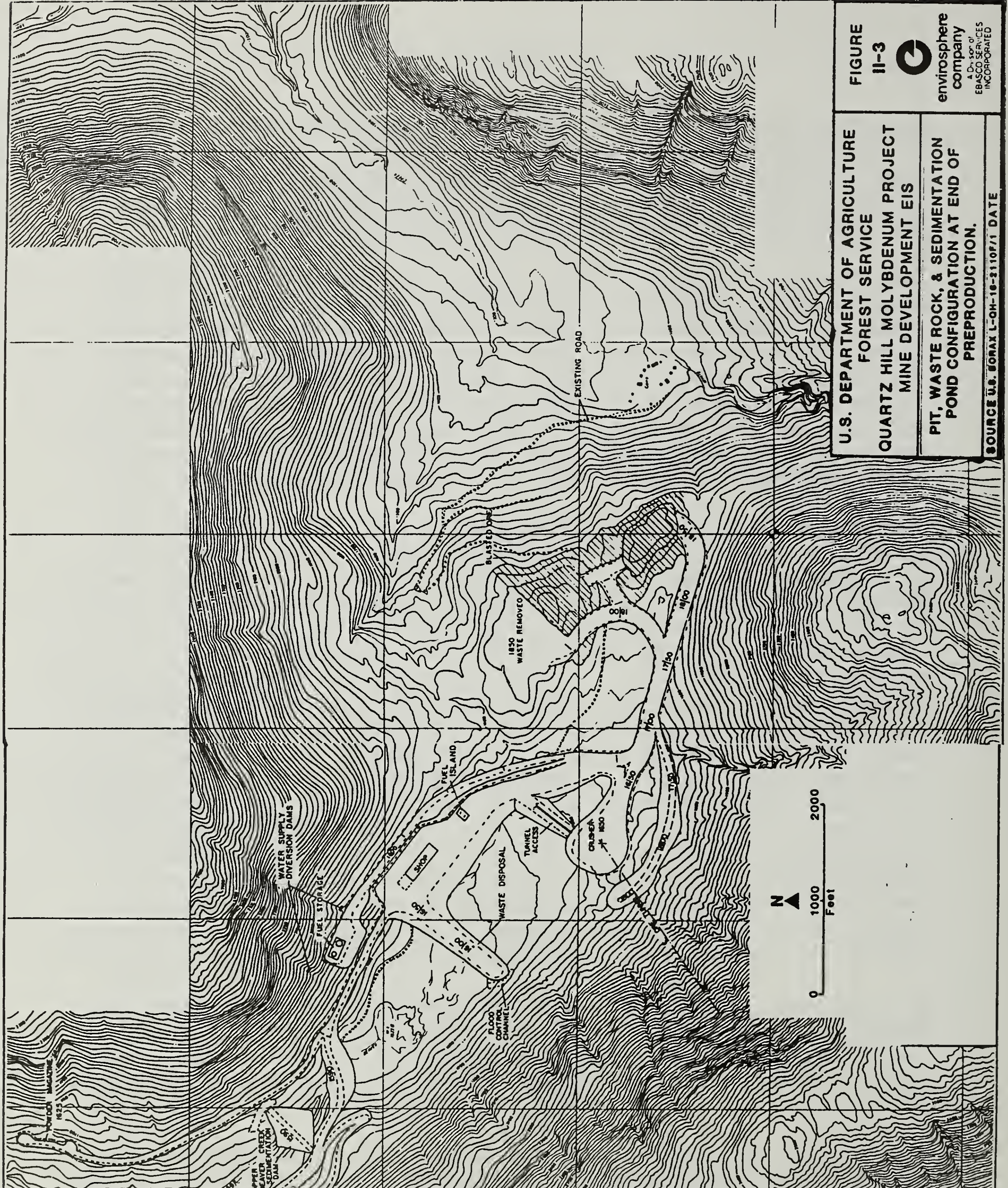
FIGURE
II-3
envirosphere company
A Division of EBASCO SERVICES INCORPORATED
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
PIT, WASTE ROCK, & SEDIMENTATION POND CONFIGURATION AT END OF PREPRODUCTION.
SOURCE U.S. BORAX L-OH-18-2110F/1 DATE
EXISTING ROAD
BLASTED ORE
1850 WASTE REMOVED
FUEL ISLAND
SHOP
TUNNEL ACCESS
CRUSHER 1850
WASTE DISPOSAL
FLOOD CONTROL CHANNEL
WATER SUPPLY DIVERSION DAMS
FUEL STORAGE
POWDER MAGAZINE 1625
UPPER BEAVER CREEK SEDIMENTATION DAM
BULK EXPLOSIVES STORAGE
1760
EXISTING ROAD
PERSONNEL HOUSING 1490
WATER SUPPLY DIVERSION DAM
N
0
1000
2000
Feet

Negligible amounts of muskeg and glacial till are projected to occur on the steep slopes of the North Ridge and Quartz Hill areas. The minor amount of overburden removed from these areas after the sixth year of operation would be hauled to the waste rock dumps.

Pit configuration at the end of the preproduction phase is shown in Figure II-3. At this time most of the permanent facilities would be in place, including the mine offices, truck shop buildings, fueling stations, yard area, primary crusher, and coarse ore conveyor. Roadway development would be completed to the Bear Meadow pit.

Mining in the open pit would be accomplished in 5 steps: drilling, blasting, loading, hauling, and dumping. Drilling would be accomplished with electric rotary drilling equipment and would consist of drilling nominal 13-3/4 in. diameter blast holes in a grid. Where required, water would be injected into the compressed air stream during the drilling process to suppress dust associated with drilling. Blasting agent would be placed in the holes and the quantity and timing of the explosions would be designed to provide optimal rock fragmentation for the loading, transport, and crushing of the ore. The blasting agents would be typical nitro-carbo-nitrate (N-C-N) explosives in various forms. At an average stripping ratio (tons of overburden per ton of ore) and a production level of 80,000 tpd, approximately 46,000 lbs per day of ammonium nitrate and approximately 460 gallons per day of fuel oil would be used for blasting. The broken rock, nominally 4 ft or less in size, would be loaded with 22-cubic yard electric shovels onto 170-ton, off-highway, rear-dump trucks for transport to the crusher or waste dumps.

Open pit development would begin in the Bear Meadow area and progress from elevation 1,850 ft to 1,350 ft during preproduction and the first 5 years of operation. After the fifth year, mining emphasis would gradually shift to the Quartz Hill area; mining from 2,650 ft down to 1,350 ft by about the fifteenth year, at which time emphasis would shift back to the Bear Meadow area.

The benches in the pit would be double benched, leaving approximately a 60 ft bench width every second bench (100 ft of elevation) to facilitate cleanup and control of snow above the haulage roads. It may be possible to not double bench in some areas. Inter-ramp and final pit limit slopes are planned to be 45 degrees. However, since final limits are not approached until about year 25 in Bear Meadow and year 35 in Quartz Hill, additional extensive rock mechanics studies and slope stability analyses would be performed to refine the ultimate slopes if necessary.

Mining would increase at a rate commensurate with the available capacity of the processing facilities. Additional processing capacity would be available by the fifth year, when both the ore extraction and processing rates would reach the nominal 80,000 tpd level. All facilities associated with the pit, mine services, and waste disposal areas required for the fully operational mine would be in place at this time.

Figure II-4 shows the mine open pit boundary and waste rock disposal area boundaries at the midpoint in the mine's life. At this time, about 1,000 ac would be committed in the mine development area for the pit; 550 ac for waste rock and overburden disposal; 150 ac for snow disposal; and 60 ac for mine services facilities, haulage, and access.

The boundaries of the mine and waste rock disposal areas at the end of the mine's life are shown in Figure II-5. A total of 2.3 billion tons of ore, waste rock, and overburden would have been removed from the pit at that time. The total amount of waste rock disposed over the 55 year mine life is approximately 900 million tons. The rock would be generally below the 0.07 percent MoS_2, but may include 75 million tons of material between 0.07 and 0.099 percent MoS_2 that would be dumped during the first 25 years of mine operation due to lack of stockpile space for lean ore. The total extent of project disturbance would be about 2,000 ac, including access roads, the mine service area, waste rock disposal and sedimentation ponds, and about 1,040 additional acres associated with the mine pit. Portions of upper Beaver Creek, White Creek, and Hill Creek, as well as about 600 ac of adjacent wetlands (muskeg) would be covered by mining activities.

3. Overburden and Waste Rock Disposal

The areas ultimately designated for overburden and waste rock disposal, including noncommercial timber, grubbed materials, slash, stumps, and other organic debris are shown in Figure II-5. Development of the overburden and waste rock disposal sites are shown in Figures II-3 and II-4. Maintenance of the overburden waste rock disposal site would include internal slopes and possible terracing to reduce erosion and maintenance of stable final slopes. Overall final slopes would be less than 40 percent. Surface runoff and infiltrated water would flow through the coarser rock beneath the waste piles to the downstream sedimentation ponds.

The waste rock disposal site would be composed primarily of rock fragments and would include all rock types encountered in mining, including gneissic country rock, low grade mineralized quartz monzonite, felsic intrusives, and post mineral intrusive rock. Residue from blasting compounds are expected to be present in trace quantities. The surface of the waste rock area is expected to have a relatively smooth, well compacted surface. Haul trucks would travel over this surface to the active dump locations.

Long term control of any portion of the waste rock found to have a potential to produce acidic mine drainage would be accomplished by developing an effective waste rock disposal plan. This plan would be developed in conjunction with normal mine planning in order to simplify methods and reduce plan costs. A mine waste dump plan would be developed during the detailed engineering and construction phase of the project. This plan would be implemented when development of the ore body begins and would continue through the life of the mine. The plan would use several proven methods and would incorporate new methods as they are developed either onsite or at other similar mines. This plan would be modified and simplified, as feasible, as knowledge is gained about the ore body and surrounding country rock.

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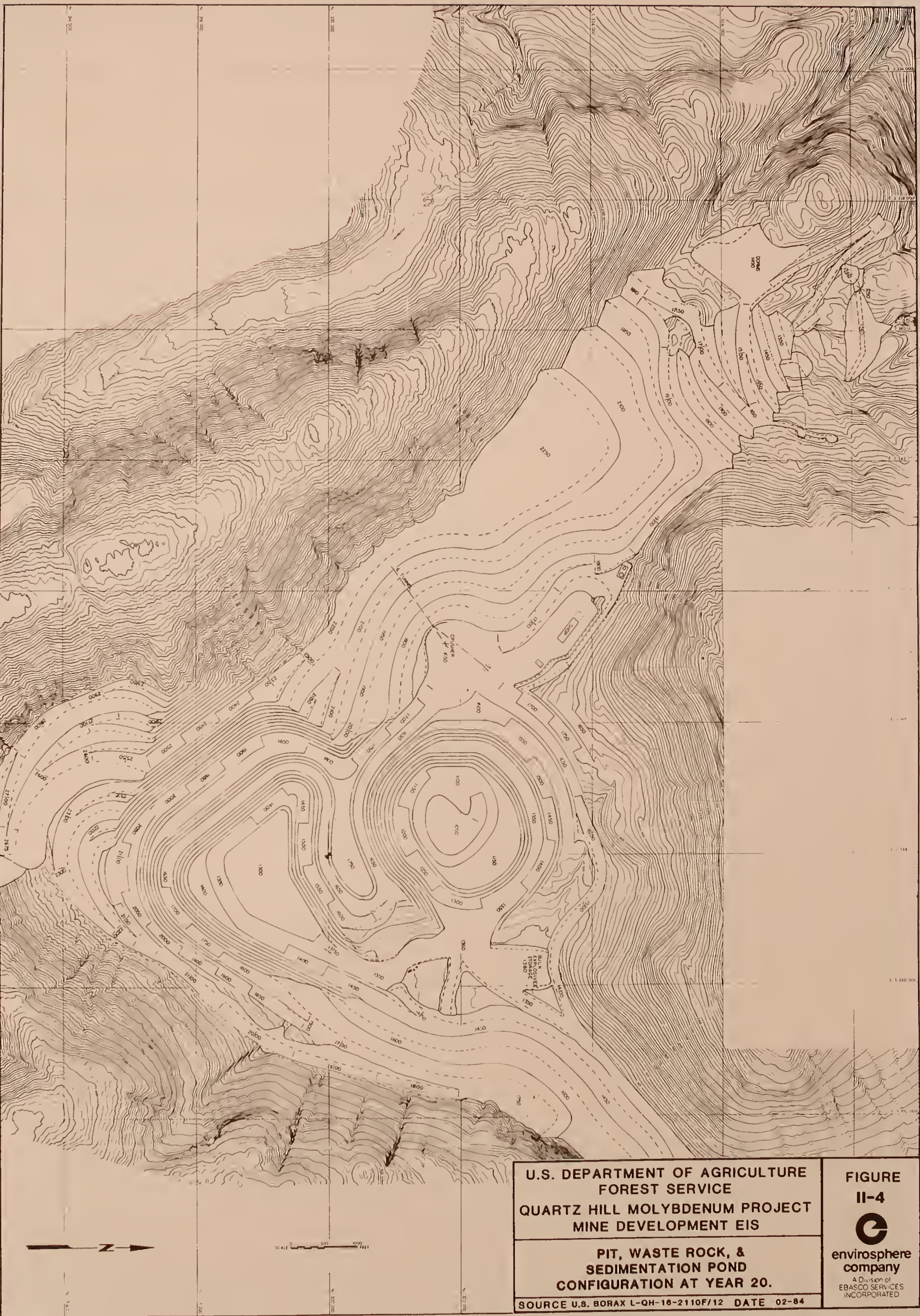
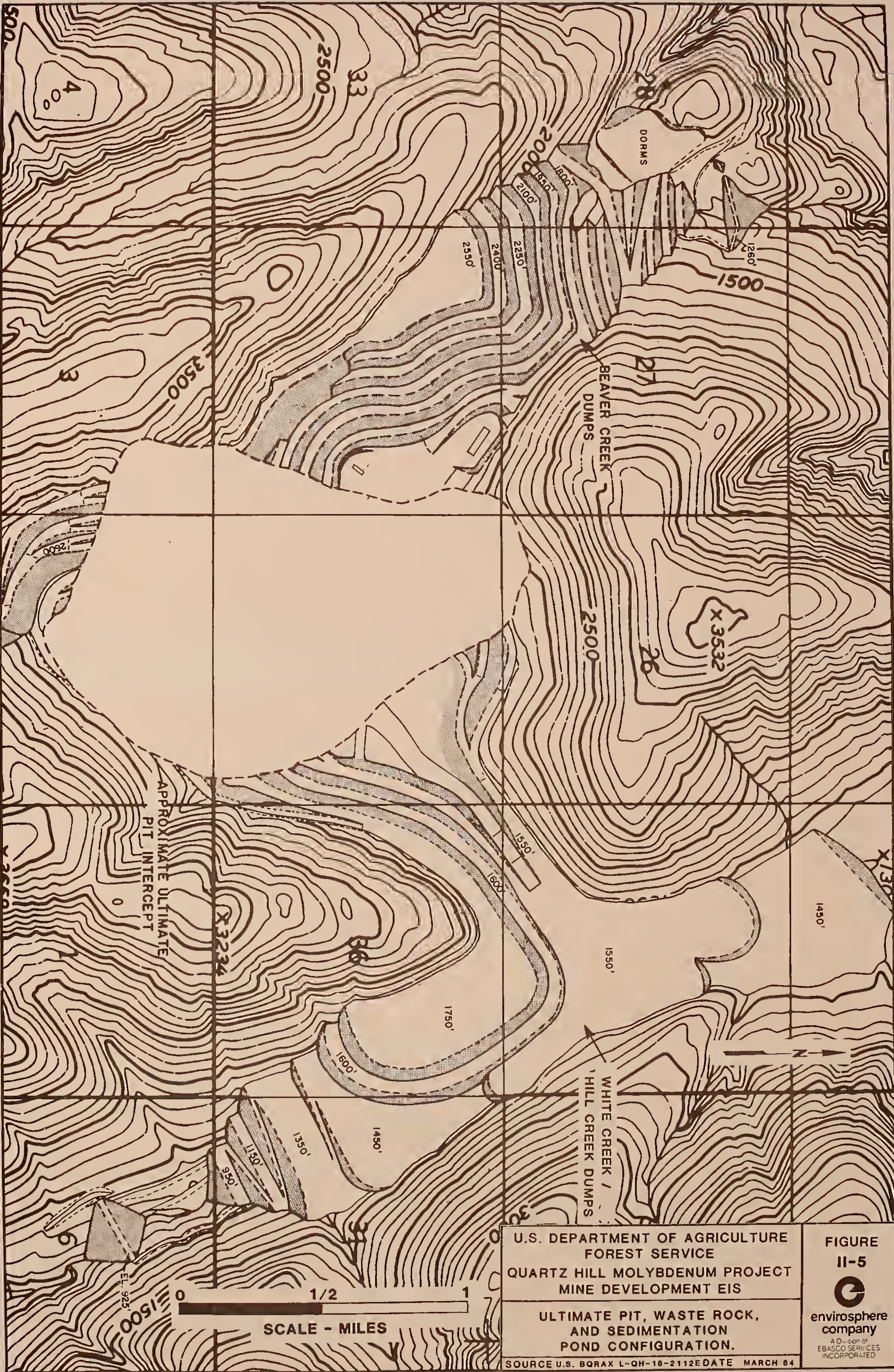

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
PIT, WASTE ROCK, &
SEDIMENTATION POND
CONFIGURATION AT YEAR 20.
SOURCE U.S. BORAX L-QH-16-2110F/12 DATE 02-84
FIGURE
II-4
envirosphere
company
A Division of
EBASCO SERVICES
INCORPORATED
N



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FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

ULTIMATE PIT, WASTE ROCK, AND SEDIMENTATION POND CONFIGURATION.

SOURCE U.S. BORAX L-QH-18-2112E DATE MARCH 84

FIGURE II-5

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Geochemical data, qualitative field evaluations, normal mine planning, normal metallurgical assays, some special quantitative assays where necessary, and special waste handling techniques would provide the basis of the waste rock plan. The primary components of the process of identifying potentially acid-producing rock that would require special handling in this plan are:

- Analyses of blasting drillhole materials. In addition to molybdenite, the drill hole material may be analyzed for copper, lead, zinc, iron, and possibly others such as total sulfur and calcium. The samples from blasting drill holes might also be subjected to other tests such as the B.C. Research "Measurement of Acid-Producing Potential" or some test to determine quantitatively or qualitatively the acid-producing or consuming potential of the sample. A reasonable data base of information on an area being mined could allow a reduction in analyses. Characterization of the waste rock could be based in part on qualitative measurements or field observations.

- Field observations. Field observations would help define specific areas within the open pit that are known acid-producing or are highly neutralizing in nature. Some indicators are change in color of waste with time, iron or sulfate content, or conductivity of drainage.

After the areas of acid-producing and consuming rocks have been identified, mining personnel would determine the type of material handling techniques that are needed to prevent acidic mine drainage. The appropriate control methods would be selected based on providing effective control at the lowest cost. The methods that have been demonstrated successfully and would be used as circumstances dictate are:

- Variable fragmentation of waste rock. Variable fragmentation would increase breakage of neutralizing rocks and decrease breakage of potentially acid-producing rocks. Depending on the neutralization potential of the waste in relation to the mine benches, explosive charges would be increased in the net acid consuming waste to produce more surface area. It may be possible to control potentially acid-producing waste by controlling the ratio of surface area for acid-consuming/producing waste. The amount of control could be determined by laboratory analyses. Where laboratory analyses indicate that fragmentation would not be sufficient to achieve neutralization, the procedure may still be of benefit since it may reduce subsequent abatement work.

- Blending. Blending is a technique of mixing potentially acid-producing material with neutralization materials in order to preclude the generation of acid. The concept of blending is the most basic method to deter acid generation. Certain factors must exist which allow the method to function properly:

(1) Abundance of neutralizing materials.

(2) Neutralizing materials that are effective.

(3) Blasting and hauling techniques that develop the proper size fractions and blends of materials.

(4) Mining equipment which can manipulate the material such that blending occurs by mixing or stratified layers.

- o Segregation or isolation. Segregation or isolation is a more complicated method of dealing with potentially acid-producing waste. It is not expected that this method would be employed frequently. Segregation is used when there is a lack of available neutralizing material. Segregation requires sealing or burial of material to minimize exposure, appropriate sealing materials or methods, and diversion of surface and subsurface water.

- o Reducing permeability to water and air. The waste rock area would be designed to minimize the infiltration of air and water. Long term protection from air or water infiltration into the waste piles would be accomplished by incorporating water resistant layers during the blending process, by crowning and covering the waste piles with the best available sealing material, by compacting the waste pile surface with equipment, and by revegetating the surface.

If the methods above are found to be inadequate in dealing with potentially acid-producing waste, chemical treatments would be considered. These techniques are extremely expensive and could impact biologically sensitive areas. Chemical treatment could possibly involving mixing a known highly neutralizing deposit with the waste. Calcareous materials such as limestone, hydrated lime, burnt lime, and liming agents could be mixed while blending the waste rock. Other chemical additives such as detergents and chemical polymers have demonstrated a mixed success in the coal industry.

4. Mine Drainage and Dewatering

Water would enter the mine pit from precipitation, runoff from uphill areas, and groundwater discharges through the pit's exposed faces and floor. The mine area would drain by gravity flow from the preproduction phase through approximately the first 6 years of operation. A system of ditches placed along the toe of the mine bench faces would drain to common discharge points. This discharge would be collected in sediment control ponds, monitored to assure compliance with NPDES Discharge Permit Criteria, then discharged to Beaver Creek and White Creek.

Beginning about year 6, the 1,300 ft bench of the Bear Meadow pit would require pumping to the White and Hill creek drainages as the primary means of pit drainage because gravity drainage would no longer be possible. Cumulative net discharge (surface and groundwater) from the exposed pit is estimated at approximately 7,500 gallons per minute (gpm) when the total area of the pit is developed. Relative to direct precipitation and surface water inflow, groundwater inflows to the open pit are expected to be negligible and to decrease over time as groundwater storage within the rock material is reduced. The mine drainage effluent chemistry is shown in Table II-2.

5. Snow Handling and Avalanche Control

Because annual snowfall at Quartz Hill may be up to 875 in., snow management would be necessary to operate the mine. It is estimated that approximately two-thirds of the accumulating snowfall on roads and at various facility locations can be plowed and side-cast with snowblowers. Remaining snow would be hauled to disposal sites within the drainages of Beaver Creek, White Creek, and Hill Creek, upstream of sediment control structures. The locations of these snow dumps would vary during the years of mining and would be located so as not to interfere with active mining operations. Some snow would be disposed in inactive areas of the mine pit.

Avalanche control would be accomplished through a combination of snow removal, avalanche area monitoring, and routine triggering of potentially unstable snow accumulations. Snow removal in high hazard areas of the mine, mill, and road areas would be performed utilizing available mine equipment. A crew of seven people, equipped with two fixed and two mobile explosive projectile launchers would monitor and trigger avalanches as required.

6. Maintenance Facilities, Ancillary Buildings, and Equipment Fleet

The mine service area would be located approximately 1,500 ft north of the crusher (Figure II-3). A 150 ft wide road for use by haul trucks and other mine equipment would extend from the mine service area to the crushing plant and open pit.

The following maintenance and ancillary facilities would be provided at the mine service area:

- service office
- maintenance shop
- parts and salvage yard
- aggregate crusher
- fuel storage and fueling station
- water supply
- explosive storage
- slurry plant (explosives mixing).

TABLE II-2
MINE DRAINAGE EFFLUENT CHARACTERIZATION[a/]

Constituent	Number of Observations	Range mg/l (or as noted)
pH, units	254	5.8-10.2
Specific conductance, umhos/cm	36	170-656
Suspended solids	43	<1-4000[b/]
Total dissolved solids	33	120-500
Total hardness	5	120-310
Calcium hardness	5	97-250
Acidity	5	2-10
Total alkalinity	5	86-330
Chloride	5	<1-7
Fluoride	5	0.6-1.1
Sulfate as SO_4	33	23-240
Silica as SiO_2	5	13-18
Total phosphorous (as P)	5	0.04-0.13
Boron	5	0.09-0.16
Nitrate nitrogen (as N)	5	0.18-4.0
Total Kjeldahl nitrogen (as N)	5	<0.1-2.6
Ammonia nitrogen (as N)	3	<0.1-2.6
Cyanide	3	<0.005-<0.020
Oil and grease	33	<0.10-44[c/]
Total organic carbon	3	9.6-17
Sodium	5	3.3-62
Potassium	5	0.3-4.9
Calcium	5	39-100
Magnesium	5	1.5-4.7
Aluminum	5	<0.020-0.050
Arsenic[f/]	27	<0.005-0.014
Barium	5	<0.020-0.070
Cadmium	18	<0.001-0.004
Chromium	36	<0.005-0.013
Copper	54	<0.005-0.094[d/]

0504K

TABLE II-2 (CONTINUED)
MINE DRAINAGE EFFLUENT CHARACTERIZATION[a/]

Constituent	Number of Observations	Range mg/l (or as noted)
Iron	33	<0.005-0.700
Lead	54	<0.005-0.020
Manganese	36	0.029-0.490
Mercury	10	<0.0002-0.002[e/]
Molybdenum	41	0.23-1.1
Nickel	13	<0.010-0.029
Silver	9	<0.005-0.006
Selenium	9	<0.002-0.018
Zinc	49	<0.002-0.028

a/ Based on Bear Meadow and Quartz Hill mine adit discharges, July 1981 to December 1983.

b/ Next highest reading was 520 mg/l.

c/ Next highest reading was 12 mg/l.

d/ Next highest reading was 0.010 mg/l.

e/ Next highest reading was 0.0004 mg/l

f/ All trace metals are dissolved portion only.

Source: U.S. Borax 1983a and U.S. Borax 1984c.

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The mine service area, as shown in Figure II-6, would require clearing and development of a level pad approximately 900 ft long by 1,400 ft (29 ac). This pad, located within the disturbed area, would require approximately 1,000,000 cu yd of rockfill material of which 500,000 cu yd would be on wetlands. A pad within the disturbed boundary would also be provided for storage and handling of blasting agents. Runoff from this area would be routed to Beaver Creek and be retained in the Beaver Creek water quality control pond. The basin would have the capacity to contain runoff from a 10-yr, 24-hr storm event and the maximum volume of nonsanitary waste water generated by the facility in a 24 hour period.

Two 80,000 gallon tanks for diesel fuel would be enclosed within earth dikes (hypalon lined) designed to contain the capacity of the tanks should a leak or rupture occur. Precipitation falling within the diked area would be removed by a small sump pump and oil separator. A 12,000 gallon gasoline tank would be buried.

The lubricant storage and waste oil holding facility would consist of four 12,000 gallon tanks and one 4,000 gallon tank. The tanks would be enclosed by a concrete block containment structure.

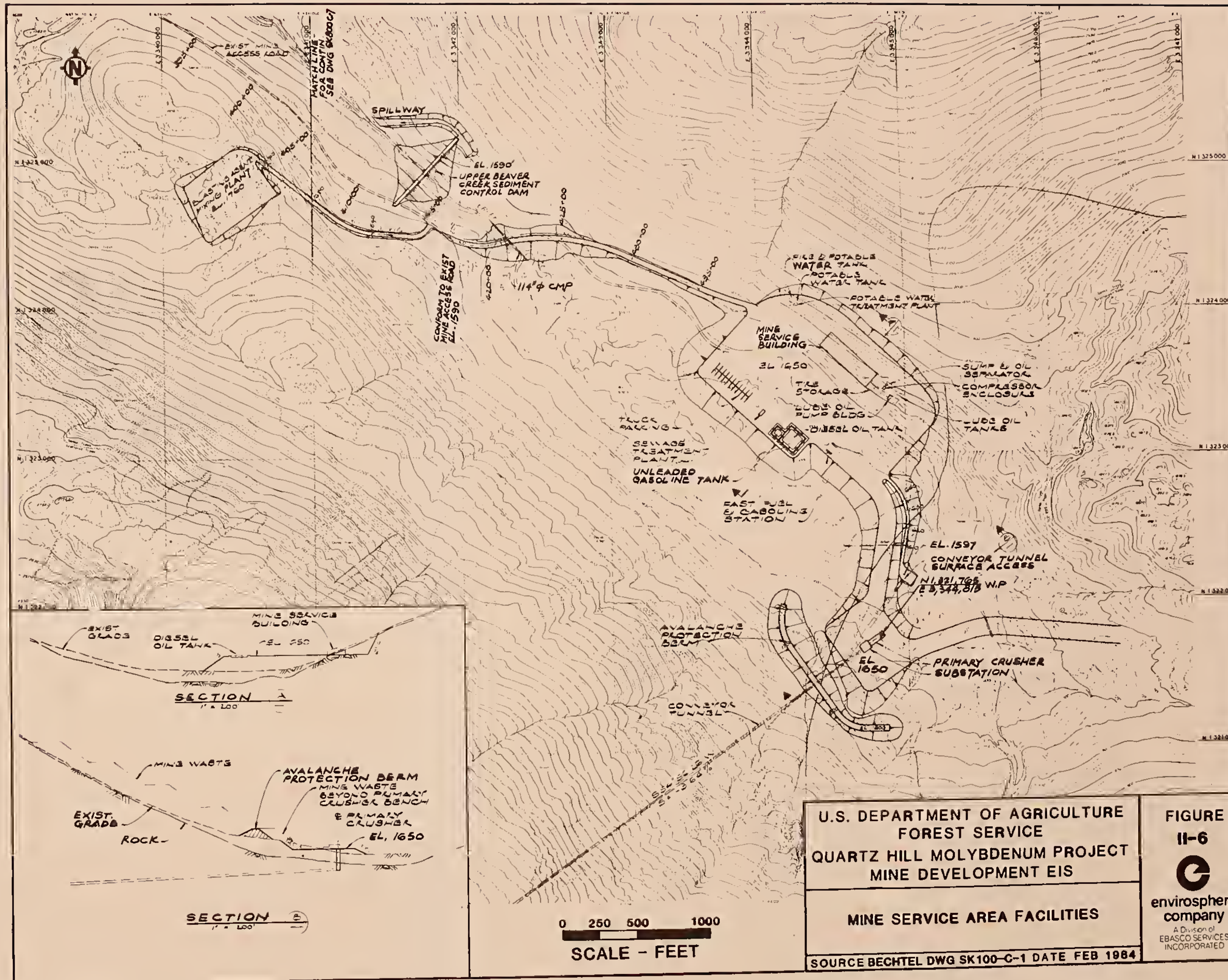
The aggregate crusher would be used primarily in the manufacture of mine haulage road construction and maintenance materials. Associated with the aggregate crusher would be a stockpile of waste rock containing an average 15,000 cu yd of feed material. Dust suppression would be employed at this facility. At full production the aggregate crusher would process approximately 660,000 tpy of feed material.

Water from a well or diversion south of the service building would be pumped to a 180,000 gallon storage tank located on an adjacent hillside. The tank would provide water for the potable water system servicing the maintenance facilities area.

Sanitary sewage and water decanted from the floor wash retention basin, the exterior sump, and the oil separator would be discharged to a drain field. The average discharge rate would be approximately 68,000 gpd.

Combustible wastes would be incinerated on site. The ash and noncombustible waste would be disposed of in an approved site. Salvageable scrap would be shipped offsite for disposal.

The mine equipment fleet anticipated at full production is described in Table II-3. This fleet would be used for all mining and ancillary functions.



U.S. DEPARTMENT OF AGRICULTURE
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QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

FIGURE II-6

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MINE SERVICE AREA FACILITIES

SOURCE BECHTEL DWG SK100-C-1 DATE FEB 1984

TABLE II-3
QUARTZ HILL PROJECT MINE EQUIPMENT

Equipment[1/]	Number of Units[1/]
Primary Fleets	
Blast hole drill, 13-3/4"	5
Electric shovel - 22 yd	7
Haulage trucks - 170 ton	44
Auxiliary	
Truck mounted drill - 6-3/4"	7
Air trac drill	8
Front-end loader - 15 yd	9
Haulage trucks - 85 ton	9
Rubber-tired dozer (400 hp)	8
Crawler dozer	7
Grader (16 ft blade)	8
Water truck	4
Snow blower	7
Gravel plant - 700 cph	2
Ancillary	
Dragline - 8 yd	2
Truck crane - 100 ton	2
Hyd. crane - 18 ton	4
Fuel/lube truck	6
Field repair truck	10
Service truck	6
Tire truck	4
Tractor/lowboy - 60 ton	2
Forklift	9
Mobile light plant	8
4WD pickups - 3/4 ton	35
Van/bus - 10 passenger	10
Suburban	2
Ambulance	3
Motor-generator set	2
Powder truck	4
Backhoe - 2 yd	2
Independent radio base	2
Pumps	NA
Computer facilities	NA
Engineering equipment	NA

1/ Preliminary estimate of numbers and types of equipment.

Source: Leonard 1984.

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7. Waste Rock and Pit Water Quality Control Structures

A water quality control facility would be constructed at the start of the preproduction phase in the upper Beaver Creek drainage. This structure would remain in place through the preproduction phase and the early years of mining and waste rock disposal area development. The location of the facility is shown in Figure II-3. An additional interim control structure would be constructed in the early years of mining in White Creek. Permanent sediment and water quality control facilities will be constructed on Hill Creek and lower Beaver Creek as shown in Figure II-5. These facilities would control suspended solids and other water quality parameters in runoff from the mine area and adjacent disturbed areas, and would be designed to contain the runoff from a 10-yr, 24-hr storm event plus provide storage for accumulated sediment.

The discharge from the interim Beaver Creek and White Creek water quality control ponds will be carefully monitored not only for compliance but to also obtain the data necessary to evaluate the effectiveness of the pond design. If it is determined that additional treatment beyond natural settling is required to meet NPDES effluent limitations and/or ADEC receiving stream water quality standards at the boundaries of the mixing zones, then the interim control facilities will be modified. This onsite experience will enable design optimization of the permanent water quality control facilities to be constructed on the project.

The water quality control ponds on Beaver Creek would contain stormwater runoff and drainage from:

- Overburden/waste rock disposal
- Snow removal disposal
- Mine pit dewatering
- Portion of mine area access and haulage roads
- Mine Service area
- Remaining undisturbed areas in the Beaver Creek watershed

The water quality control ponds on White and Hill Creeks would contain runoff from:

- Overburden/waste rock disposal
- Snow removal disposal
- Mine pit dewatering
- Portion of mine access and haulage roads
- Remaining undisturbed areas in the White and Hill Creek watersheds

The ponds would be dredged when the accumulated sediment reaches maximum sediment storage capacity. Dredged sediment would be disposed of in engineered containments in the waste rock disposal areas upstream of the water quality control structures. If feasible, this material would be utilized as topsoil for reclamation purposes.

Outlet structures would be used to maintain minimum downstream flows for the protection of salmon and trout resources in receiving streams.

Upper Beaver Creek Water Quality Control Facility

A water quality control dam on upper Beaver Creek would be built at the start of construction to control sediment and treat the water, if necessary, during the initial years of mine development. The location of the dam is shown in Figure II-3. All mine area surface disturbance would be confined to the Beaver Creek basin during these years. After several years of mining, the waste rock area would encroach on the reservoir. At that time, water quality control would be accomplished by the lower Beaver Creek facility.

The upper Beaver Creek pond would control runoff from a drainage area of 1.6 sq mi, with a reservoir volume allowing for sediment and waste rock encroachment. The dam would be rockfill with glacial till core with a total embankment fill of 310,000 cu yd. Approximately 5,000 cu yd of fill would be below the ordinary high water mark (OHWM) of Beaver Creek. The remaining 305,000 cu yd of fill would be within adjacent wetlands. The decant structure would be connected to a concrete outlet pipe placed under the dam. The emergency spillway would be designed to pass the probable maximum flood (PMF).

White Creek Water Quality Control Facility

During the early years of mine development, a water quality control dam on White Creek would be constructed and operated to impound runoff from the waste rock disposal area. This pond would also collect runoff from a snow disposal area as well as mine drainage. In later years, as the waste dump encroaches on the reservoir, it would be necessary to construct a water quality control facility on lower Hill Creek.

The drainage area above the White Creek dam would be 3.0 sq mi. The reservoir volume includes storage volume for sediment and waste rock. The dam would be a rockfill structure. Total embankment fill would be 850,000 cu yd, of which 10,000 cu yd would be below the OHWM. Approximately 25,000 cu yd of the fill would be within adjacent wetland areas. The decant structure would connect to a concrete outlet conduit placed under the dam. The emergency spillway, a channel in the dam abutment, would be designed to pass the PMF.

Lower Beaver Creek Water Quality Control Facility

The dam site for the permanent control facility at Beaver Creek is shown in Figure II-5. The natural tributary drainage area of the reservoir is 2.1 sq mi. An allowance in the storage capacity would be provided for sediment. Waste rock disposal would not encroach on the

reservoir. As presently envisioned, the dam would be constructed of compacted rockfill with a glacial till core with a total fill volume of 1,400,000 cu yd. Fill below OHWM would total 14,000 cu yd. Approximately 1,000 cu yd of fill would be in adjacent wetlands. Decanting would be accomplished by a gated conduit on the dam's upstream face with connection to a diversion conduit under the dam. The emergency spillway would be an open channel and would have capacity sufficient to pass the PMF.

Lower Hill Creek Water Quality Control Facility

The site selected for the control facility on Hill Creek is approximately 1.8 mi upstream from its confluence with the Keta River. At this location, the natural tributary drainage area is approximately 12 sq mi. As presently envisioned a reservoir, allowing storage for sediment, would be constructed to replace the White Creek control facility after several years of mining.

It is planned to deposit waste rock in the channel of Hill Creek downstream of the mine but upstream of the control facility. After 20 years of mine operation, the accumulated waste rock would occupy much of the reservoir volume; however, the reservoir would be designed so that the required storage would be obtained within the voids of the waste rock, assuming a void ratio of 30 percent.

The dam would be constructed of compacted rockfill with a glacial till core. Total embankment fill would be 3,600,000 cu yd with 25,000 cu yd below OHWM. No additional wetlands would be affected by fill. Diversion during dam construction would be through a tunnel in the dam abutment. This tunnel would be incorporated into a decant system. An open channel emergency spillway on the right abutment would have sufficient capacity to pass the outflow from the PMF.

8. Mine Reclamation

Reclamation would have a direct effect on project cost, bonding requirements, and ultimate environmental effects. It would be an essential part of the final project as implemented. Because it is difficult to predict how reclamation technologies and economics will change over the expected 55 year mine life, reclamation planning for the project emphasizes reclamation goals and standards, rather than technologies. Current technologies are assumed in this EIS as the means of achieving the goals and standards, but the Forest Service and the mine owner/operator would retain the flexibility to refine the specifics of reclamation by mutual agreement and thus avoid being restricted to outdated and obsolete reclamation technologies. The following reclamation measures are part of the plan of operation as required in 36 CFR 228. It will undergo periodic formal review to assure the applicability and success of reclamation measures used at all stages including post operational phases.

The overall goal of the reclamation plan is to reclaim the land so that it is consistent, to the maximum extent feasible, with the purposes for which the Misty Fiords National Monument was established. Self-maintaining reclamation established as soon as practicable after disturbances of an area has ceased would be the second goal of the reclamation plan.

In general, the reclamation standards are that reclamation should begin as soon as reasonably practicable and should be complete within two years after abandonment of an area. Reclamation would be considered acceptable after five years of stable, viable growth with no maintenance or fertilization. The reclamation bond provided by the owner/operator would be reduced as particular areas of reclamation are accepted by the Forest Service or when the owner/operator has demonstrated sufficient advances in reclamation technology and economics to warrant the reduction.

Reclamation is discussed below in two major time frames. Within each, individual goals, measures, and components are discussed.

Operational Reclamation

Operational reclamation would take place during the life of the mine. This type of reclamation would occur during construction, operation, and temporary shutdowns. Measures that would need to be taken for operational reclamation include:

- Determining any necessary stabilization needs for all disturbed areas not to be used for the following two years. Where appropriate, these areas would be seeded with grasses to prevent erosion.

- Seeding and stabilization of areas that would be disturbed one time only as soon as possible after disturbance, but within constraints dictated by seeding and growing seasons.

- As disturbed areas are abandoned during operation (e.g., parts of waste rock piles, quarries, certain benches of the mine pit), they would be covered with a topsoil mixture and revegetated according to procedures described below for waste rock piles. The topsoil mixture will primarily consist of glacial till.

Post-Mining Reclamation

The goal of reclamation is to shape, stabilize, and revegetate disturbed areas so that when reclamation is complete, disturbed areas will not unnecessarily conflict with natural land forms and will not require maintenance. In keeping with this goal, all structures, equipment and facilities that would themselves unnecessarily conflict

or would present a hazard to wildlife or people would be removed or covered to prevent conflicts or hazards. Also, structures, equipment, and facilities that could cause degradation of water quality would be removed.

Reclamation by project component includes:

a. Waste Rock Disposal Areas - Vegetate the surface of the waste rock areas with native species to control erosion and runoff. The waste rock areas would be shaped before reclamation with a "crown" to control infiltration of runoff, to prevent ponding, and to provide adequate surface drainage. The waste rock areas would also be contoured to provide drainage channels and swales to carry surface runoff. To ensure the success of revegetation, a topsoil mixture composed primarily of glacial till with some muskeg intermixed would be spread over the surface of the areas to be revegetated, including the faces of waste rock lifts. The optimum depth of topsoil mixture should be 12 to 18 inches (18 inches was used with superior results at Island Copper) according to Pelletier (1984).

   The topsoil mixture would come from stockpiles located at one edge of the mine waste rock areas in the White Creek valley and the Beaver Creek valley, and near the tunnel waste rock area in the Tunnel Creek valley.

b. Water Quality Control Ponds and Dams - The primary objective of reclamation of the ponds and dams would be to assure that there will be no catastrophic breaching of the dam in the future that would cause a mudslide and flood wave with severe consequences to the stream.

   The water quality control ponds would remain operational until sediment production from the upstream area has returned to near natural levels.

c. Mine Service Facilities - Unless otherwise specified in permits, all structures on National Monument land would be removed. Foundations would be covered to a suitable depth with topsoil mixture, the area shaped to resemble natural contours, and vegetated. Foundations may have to be broken up to provide for acceptable ground water infiltration.

d. Mill Site and Power Plant - Unless otherwise specified in permits, all structures would be removed, the foundations covered, and the area shaped to resemble natural contours and vegetated. Suitable overburden would be stockpiled at one edge of the site or waste rock pile to serve as a topsoil mixture.

e. Access Road - If access to the project area is no longer required, the access road would be reclaimed. All structures, including bridges and culverts, would be removed, the approaches shaped to as

near a natural contour as practicable, water bars constructed, and the surface ripped and seeded. Some fills, particularly those on intertidal areas and riparian zones, may also require shaping or other treatment. To speed up revegetation of areas of special importance for visual or habitat reasons, the topsoil mixture in storage would be used to cover the road and cut slopes as appropriate.

f. Wharf Facilities - Wharf facilities would be removed when no longer required, disturbed land areas would be shaped to resemble natural land forms, covered with topsoil mixtures, and vegetated with native species.

g. Tunnels - All salvageable equipment and other equipment as required would be removed from the tunnels. The ends of the tunnel and appropriate locations within the tunnel would be plugged and sealed. Portal areas would be shaped to blend with existing land forms and vegetated with native species.

h. Water Supply Facilities - All structures and foundations would be removed or covered as appropriate. Dams would be stabilized. Pipelines would be removed or covered, all bridges and culverts would be removed, and the road would be ripped and seeded.

i. Water Reservoirs - As with sedimentation ponds, dams would be stabilized. Access roads would be ripped and revegetated. All bridges and culverts would be removed.

j. Topsoil Storage Areas - After the topsoil is removed to reclaim other areas, the storage area would be shaped to blend with natural land forms and vegetated with native species.

k. Townsite/Campsite - Assuming no further requirement for them, all structures would be removed. Foundations would be removed or broken up and covered. The area would be shaped to blend with natural land forms and vegetated with native species.

l. Utility Corridor - Any utility corridors that were no longer needed would have all structures removed and any unstable areas would be treated for erosion control and revegetated.

m. The Open Pit - The opportunities to reclaim the open pit are somewhat limited. The pit area would be allowed to fill with water and would become a privately owned lake with terraced rock walls. Overflow from the lake would be directed to drainage channels contoured into the surface of the waste rock disposal area. Topsoil application and revegetation of some benches would be performed as the benches are abandoned.

n. Peripheral Facilities - Peripheral facilities such as weather station sites and navigation aids would be removed and the areas treated to resemble natural conditions.

B. PRIMARY CRUSHER: NORTHWEST EDGE OF PIT

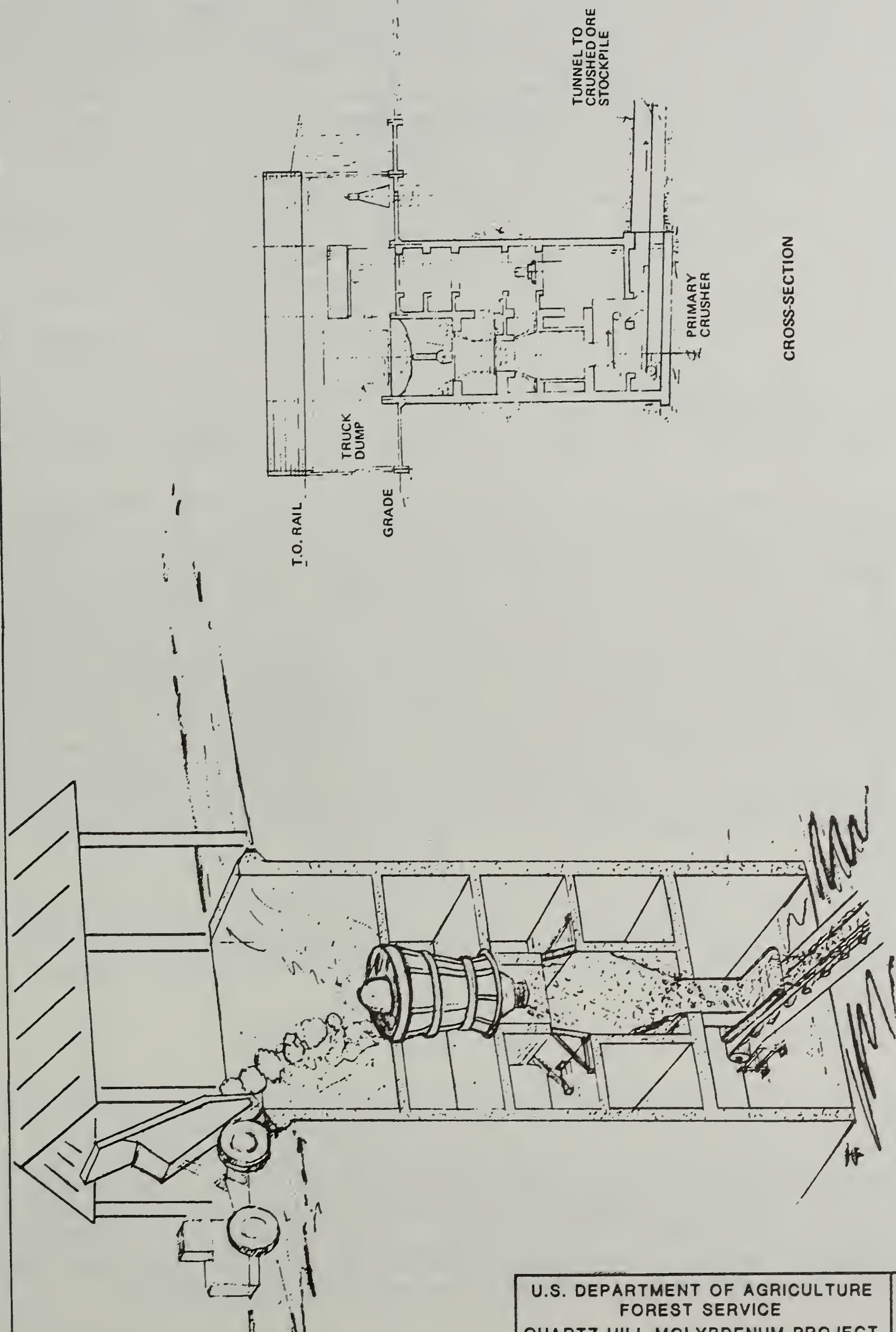
The location of the proposed crusher would be at the northwestern edge of the open pit as shown in Figure II-3. An area around the crusher building would be developed to provide maneuvering room for 170 ton capacity, end-dump trucks. Trucks would dump into the crusher at both ends of the crusher building. Approximately 5 ac would be cleared for crusher construction, the pad area, and various access roads. Muskeg cleared from the area would be hauled to an engineered site in the waste rock disposal area. Merchantable timber would be used onsite to the extent possible, with excess sold to a commercial operator. Noncommercial timber and brush would be placed in a disposal area. An excavation, 50 ft by 25 ft by 100 ft (approximately 4,600 cu yd of material), would be required to place the crusher. The excavated material would be used as fill in the crusher pad area.

During mine operations the run-of-mine ore would be delivered by truck to the crusher and dumped inside the crusher building. A rock breaker located at the dump pocket would break oversize rock for passage through the crusher. The crusher would be a 60 in. x 89 in. gyratory crusher with a nominal 8 in. open side setting producing ore less than 14 in. in diameter. A conceptual drawing of the facility is shown in Figure II-7. Output from the crusher would pass into a 360 ton surge pocket below the crusher before feeding via a belt feeder directly to the conveyor system for transport to the mill. Crusher facilities would be partially below existing grade. Crushing would be a dry process and dust would be controlled with water sprays at the dump pocket and hooded transfer points. Exhaust from hoods would be directed to a baghouse where fine particulates would be collected and routed back to the conveyor line. Electric power transmitted through the ore conveyor tunnel from the Tunnel Creek power plant would be used to power the crusher.

The crusher would be utilized throughout the mine's life. At the end of mining, the crusher facility would be reclaimed by removing or covering all crusher equipment, recontouring and refilling the crusher facility excavation, reseeding the area, and planting seedlings. Special soil treatments and amendments would be utilized if needed to improve revegetation success.

C. ORE TRANSPORT: ORE CONVEYOR

Crushed ore would be conveyed from the crusher to the coarse ore stockpile at the mill site at Tunnel Creek via an approximately 18 ft by 14 ft (minimum), 22,000 ft long tunnel as shown in Figure II-1.



U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE QUARTZ HILL MOLYBDENUM PROJECT MINE DEVELOPMENT EIS	FIGURE II-7
CRUSHER	envirosphere company A Division of EBASCO SERVICES INCORPORATED
SOURCE U.S. BORAX DATE MAR 83	

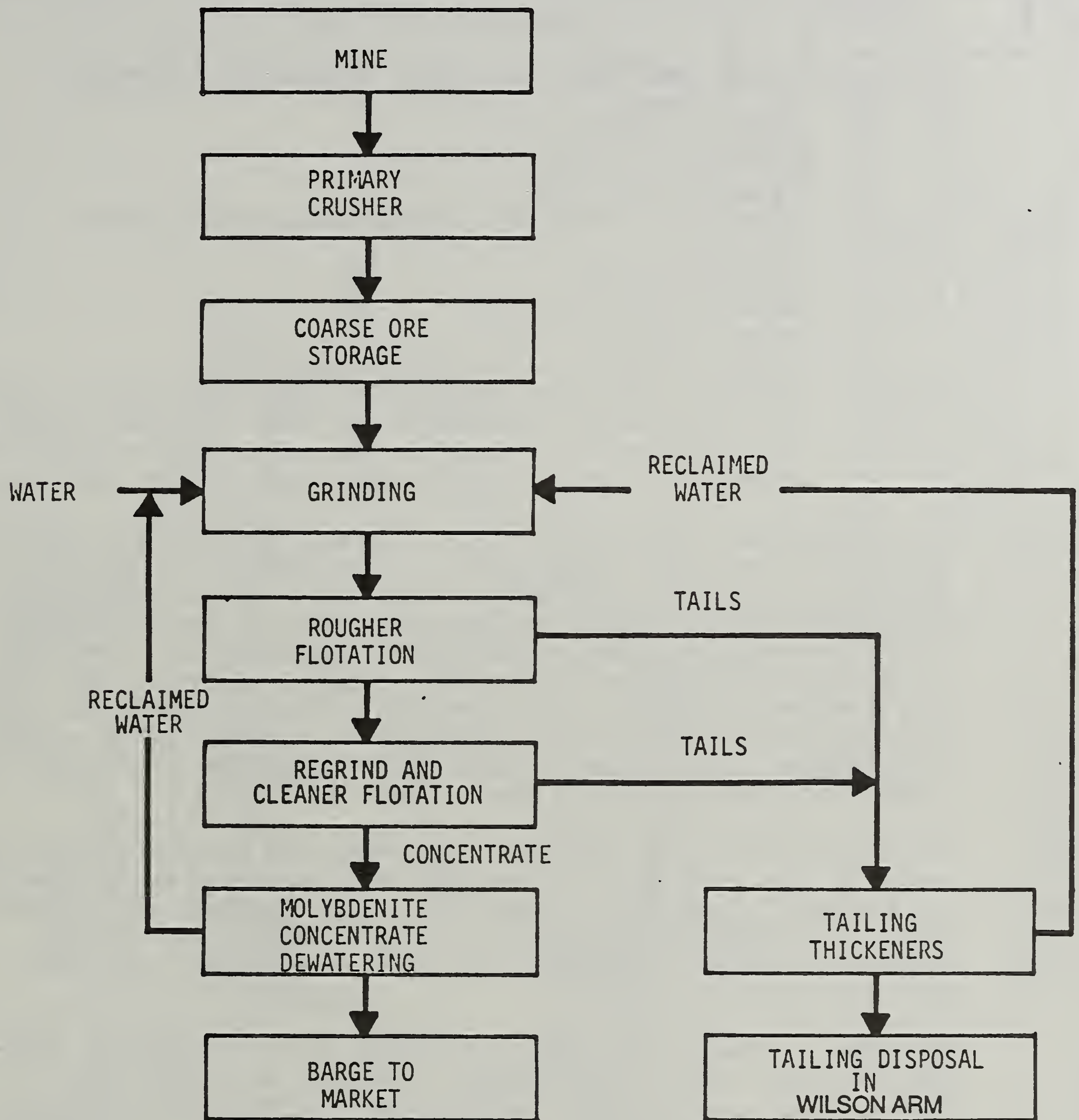
Construction of the tunnel would disturb approximately 4 surface acres at each end. Muskeg would be removed and deposited in the waste rock disposal area. Merchantable timber would be used to the extent possible on the job site as cribbing, building material, etc. or sold. Waste timber would be placed in a disposal area. Tunnel construction and excavation would remove approximately 225,000 cu yd (natural volume before bulking) of waste rock. The tunnel would likely be constructed by crews working from the Tunnel Creek end. Waste from the Tunnel Creek end would be used for foundation material in the mill area to the extent possible, with any excess disposed in a waste rock disposal area. An access road for construction and operation would be required. An underground rail system would be used for removal of rock from the tunnel heading. The other types and numbers of construction equipment used to develop the ore conveying tunnel have not been determined. Appropriate sediment and dust control would be employed to minimize impacts from construction and waste rock disposal. Groundwater flowing into the tunnel would be routed to a sedimentation basin designed for these flows and located near the tunnel portal in Tunnel Creek. Sediment release from the basin would be controlled either through detention time or other means of treatment to meet NPDES effluent criteria. This water would then be discharged to Tunnel Creek.

During the operation of the tunnel, a single flight belt conveyor would transport the nominal 8 in. and smaller ore from the crusher to the coarse ore stockpile. Conveyor equipment would include a belt feeder to feed ore from the crusher to the conveyor, a dust collection system, and a 60 in. wide belt conveyor. The conveyor system would generate power by utilizing the downhill movement of the coarse ore. Estimated power generated by the conveyor system would be approximately 1.0 MW at a processing rate of 80,000 tpd. No dust collection system other than the system at the transfer points mentioned in the crusher description would be incorporated into the tunnel. Water intercepted by the tunnel would continue to be collected in the settling pond at the downstream end of the tunnel in Tunnel Creek, with clear water overflow routed to the process water tank to be utilized as part of the process water needs.

When the mine is abandoned the tunnel would be sealed and the tunnel openings would be recontoured, reseeded, and replanted. The belt conveyor equipment would be removed from the tunnel for salvage prior to tunnel sealing.

D. PROCESSING FACILITIES: TUNNEL CREEK

A deposit such as Quartz Hill involves processing a large amount of ore with only a small percentage of the ore ultimately separated as the molybdenum concentrate. On an average basis, less than 3 lbs of molybdenite is produced for every ton of ore processed. Processing in this case includes grinding, classification, flotation, thickening, filtration, and shipment (Figure II-8). This processing is required to physically separate the molybdenite particles from the host rock and to produce two major output streams: one which is predominantly



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QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

PROCESSING FACILITIES FLOWCHART

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SOURCE U.S. BORAX DATE NOV 83

FIGURE II-8

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molybdenite mineral particles, and another which is a slurry containing host rock particles. This molybdenite product is referred to as the concentrate and the host rock particles (predominantly quartz monzonite and quartz) are referred to as the tailings.

The Tunnel Creek processing site would include the following:

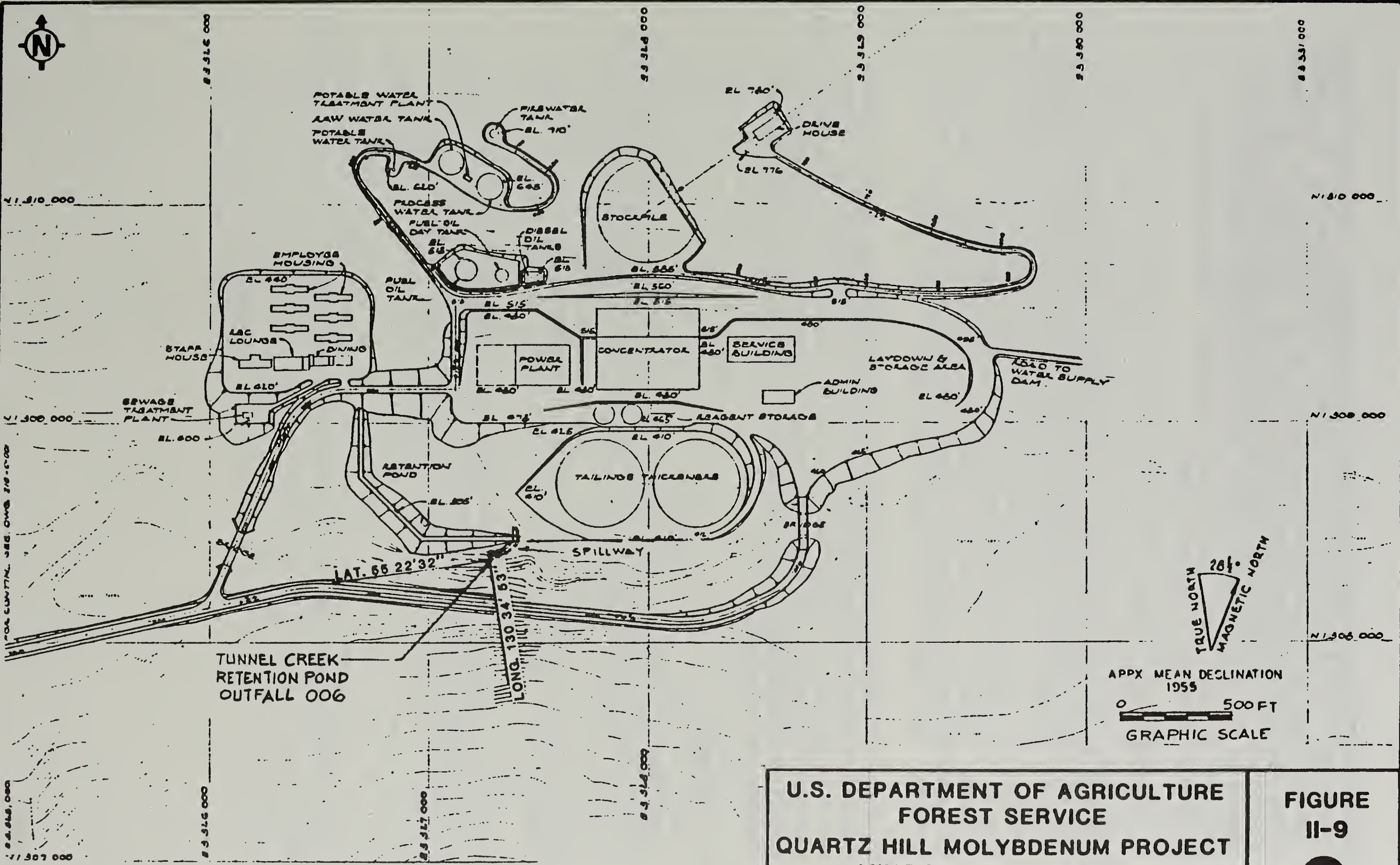
- Coarse ore stockpile
- Grinding facilities
- Flotation facilities
- Concentrate dewatering, storage/shipping facilities
- Thickeners
- Service buildings
- Administration buildings
- Reagent storage
- Disposal areas for waste rock from tunnels
- Ancillary facilities (water supply facilities [wells and/or diversion], water treatment plant, water and fuel storage tanks, wastewater treatment plant, site runoff retention and sedimentation pond, a power plant, and employee housing).

The concentrator and related facilities would be located on the north slope of Tunnel Creek (Figure II-1). A detailed plot plan of the processing facilities is shown in Figure II-9. Surface disturbance associated with the processing site (inclusive of power plant and ancillary structures) would total approximately 210 ac. Benching, involving extensive grading, would be required to prepare the site for the permanent facilities. Clearing would be accomplished only within the construction areas, with organic materials deposited at a waste rock disposal site. Topsoil would be stockpiled for future use. Topsoil stockpile locations have not been identified.

An access road to the area would originate from the mine access road south of its crossing of Tunnel Creek. The access road would be graded to a width of 36 ft with an additional 17 ft clearance on each side to permit transport of preassembled 60 ft wide modules during the construction phase. Maximum grade would be 6 percent. The road surface would be gravelled.

In order to reduce the volume of effluent and the demand for fresh make-up water, several recycling points would be used in the concentrator process, including final tailings thickener overflow, roughener/scavenger flotation thickener overflow, final concentrate thickener overflow, concentrate filtrates, power plant wastewater, ore transport tunnel drainage, concentrator site runoff and washdown, and cleanup water.

The wastewater and sewage from the concentrator area would be treated at a secondary treatment plant near the housing area on Tunnel Creek. The average flow to this plant from the concentrator area would be approximately 32,000 gpd. Effluent from this plant would be routed to the tailings line for discharge.



Note:
Grid shown is Alaska State Plane Coordinate System, Zone 1.

U.S. DEPARTMENT OF AGRICULTURE
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QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

PLOT PLAN OF PROCESSING FACILITIES AT TUNNEL CREEK

SOURCE | DATE

FIGURE II-9

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Drainage from developed areas would be conveyed by a series of ditches and culverts to a retention pond having a design capacity for runoff from a 10-yr, 24-hr storm event. During mine construction, collected water would be treated to meet NPDES effluent limitations and discharged to Tunnel Creek, but during mine operation it would be pumped to the process water tank. During shutdown of the ore processing facilities, overflow of stormwater from the pond will discharge directly to Tunnel Creek.

1. Coarse Ore Storage

The ore would discharge from the belt conveyor into an uncovered coarse ore stockpile equipped with water sprays for dust control. Plans call for live storage for one day's production of ore. An additional 4 day supply for the concentrator would be available from dead storage. The coarse ore stockpile would provide sufficient surge capacity to ensure a steady supply of ore to the subsequent grinding steps. Ore would be reclaimed from the stockpile by apron feeders operating in reclaim tunnels, one tunnel for each grinding line.

Dust collected at transfer points would be ducted to a wet scrubber located at the mouth of each reclaim tunnel. Scrubber dust slurry would be pumped to the grinding section. Runoff from the uncovered ore storage pile bench would be collected and routed to the plant site runoff retention pond, which would be sized to contain the 10-year, 24-hour storm runoff.

2. Grinding

The coarse ore feed to the plant would consist of ore pieces nominally 8 in. in size and smaller. The feed particles would be a combination of quartz monzonite, quartz, molybdenite, and accessory minerals contained within the host rock. To prepare the feed for further processing, it is necessary to grind this material to a size small enough to free the molybdenite bearing minerals from the host rock.

Crushed ore would be withdrawn continously from the coarse ore stockpile by feeders, and then transported by belt conveyors to the semiautogenous grinding (SAG) mills, operating in closed circuit with screens, followed by ball mills in closed circuit with sizing hydrocyclones. Water would be added in the mills, and the operation would be "wet". The solids/water mixture, or slurry, of about 60 percent solids, would move through the mills, with the actual grinding resulting from the tumbling action of the ore and balls in the rotating mills.

In the ball mill circuit, oversize material would discharge from the bottom of the cyclones to be recycled to the ball mill. Undersize material, considered the finished grinding circuit product, would overflow the cyclone and would flow by gravity as a 30-35 percent solids slurry to the flotation concentration step.

3. Flotation

In a flotation process, a slurry of finely ground ore, water, and reagents would be passed into flotation cells (or tanks) where the slurry is subjected to agitation and aeration. Flotation separation would be accomplished by entraining air in the slurry in a series of mechanically agitated cells in the presence of three types of specific-surface-active reagents, including:

- Those that promote frothing (frothers);

- Those that promote adherence of the desired mineral to the air bubbles (collectors); or

- Those that depress certain minerals and wastes so as to minimize their tendency to float (depressants or modifiers).

The froth containing the molybdenite concentrate would overflow the tops of the cells, and the unwanted tailings slurry would discharge from the bottom of the cells. In subsequent steps, the molybdenite would be reground and further purified into the final product by additional flotation steps. The proposed reagents to be used at Quartz Hill and their projected rates of consumption are listed in Table II-4. Reagents are distributed with molybdenite concentrate and tailings slurry. (This distribution is being defined in the pilot plant testing program.)

The flotation operation at Quartz Hill would be carried out in as many as 10 stages. The first two would entail bulk separation, thereby producing a rougher concentrate containing about 2 to 7 percent molybdenite. The rougher concentrate would be reground in a smaller ball mill and subjected to the remaining 8 stages of cleaning flotation, with further interstage grinding, to upgrade the concentrate progressively to 90 to 97 percent molybdenite.

4. Reagent Handling

Flotation reagents would be received at the site in portable tanks, bins, sacks, barrels, or other containers and would be stored, mixed, and dispensed from the reagent building (Figure II-9). The mixed reagents would be pumped to the flotation area and fed into the process with mechanical feeders.

TABLE II-4

MILL REAGENT USE

Reagent 1/	Purpose	Usage 2/ lb/ton	Usage lb/day for 80,000 ton/day
Lime	pH modifier	0.134	10,720
Sodium Silicate	gangue dispersant	0.063	5,040
Dowfroth 250 1/	frother	0.003	240
Methyl Isobutyl Carbinol (MIBC)	frother	0.088	7,040
Stepanfloat 85-L 2/	frother/dispersant for the collector	0.011	880
No. 2 Diesel Fuel Oil	molybdenite collector	0.634	50,720
Nokes Reagent 3/	depressant for Cu, Pb, Fe	0.054	4,320
M-502 4/	flocculant	0.199	15,920
Aerodri 100 5/	surfactant	0.0002	16

1/ During the pilot plant operations several reagents were tested to find suitable alternatives. It was found that MG700 could be replaced by M502 or SF330 (a cationic polyamine). Sodium silicate could be partially replaced by CMC-7 (carboxyl methyl cellulose). Dowfroth 250 could be replaced by ALFOL 6 (alcohol).

2/ From Bulk Sample Pilot Plant flotation testing from October 24 to 27, 1983. Based on fifty checks of reagent addition rates.

3/ Polypropylene methyl ether ($CH_3-(O-C_3H_6)_x-OH$).

4/ Sodium fatty alcohol ether sulfate in alcohol-water solution.

5/ 43.5 percent phosphorus pentasulfide and 56.5 percent NaOH.

Source: U.S. Borax 1984a.

The sumps inside the reagent buildings would be of sufficient size to handle the largest possible spill. Any spilled reagents would be returned to the flotation process. Reagent containers would be recycled or disposed of as approved.

5. Concentrate Drying and Packaging

After molybdenite particles are extracted from the flotation cells as a froth they would be pumped to a thickener. Since the thickener underflow still contains water (approximately 40 to 60 percent water by weight), further dewatering would be necessary to facilitate shipment of the concentrates. This would be accomplished in pressure filters. Approximately 130 tpd of molybdenite concentrate containing about 8 to 10 percent moisture would be produced in the plant and placed in containers for shipment to market or a refinery. The containers would be stored at the mill site in a concentrate storage building then trucked to the wharf prior to shipment.

6. Tailings Thickeners

Tailings from the flotation cells would be transferred in a concrete launder (an open channel) extending to the tailings thickeners at the concentrator site. The thickeners would be on the north side of Tunnel Creek adjacent to the concentrator. Overflows from the tailings thickeners would be returned to the water process tank to be reused as make-up water in the process.

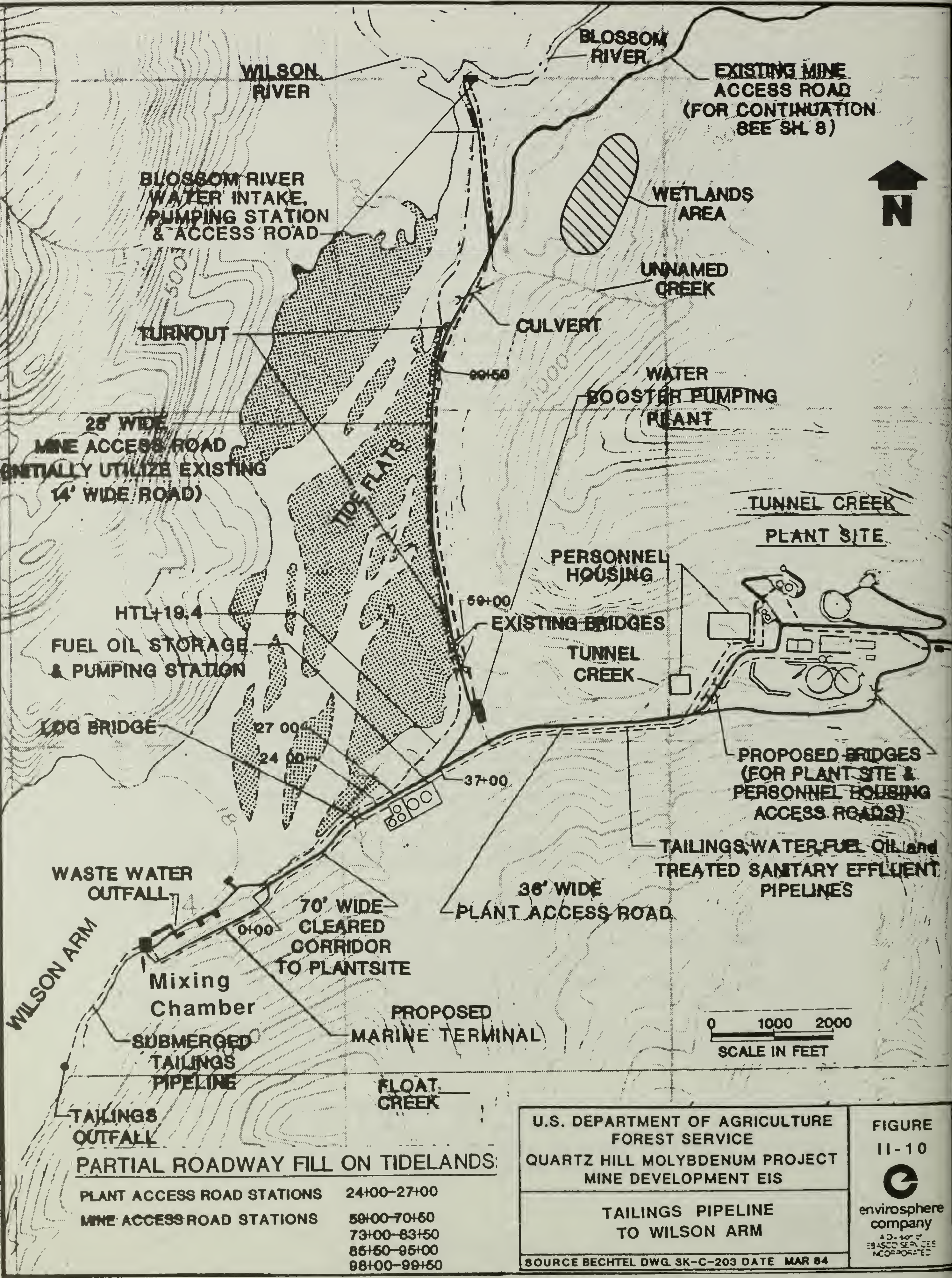
7. Reclamation at Closure

Reclamation of the plant site would consist of disassembly and removal of all plant structures. The area would be graded and recontoured. Topsoil from storage piles would be spread over the disturbed area. Accessways to underground facilities, including buried conveyors, would be sealed. Any remaining stockpiled topsoil would be incorporated during recontouring. The reclaimed area would be reseeded and replanted using native species of grasses and tree seedlings in accordance with Forest Service guidelines.

E. TAILINGS DISPOSAL FACILITIES: WILSON ARM MARINE DISPOSAL

The proposed project involves the use of the Tunnel Creek mill with tailings disposal into Wilson Arm. During Tunnel Creek mill operations, approximately 79,850 tpd of tailings would be discharged based on an ore production rate of 80,000 tpd. The tailings would leave the thickener with a solids content of about 40 to 50 percent by weight. This mixture would require a water supply of approximately 16,600 gallons per minute (gpm). The expected liquid phase and solid phase concentrations of the tailings are presented in Tables II-5 through II-7.

Tailings from the mill site thickener would be transported by gravity pipeline to an outfall at Wilson Arm as shown in Figure II-10. Two parallel pipelines would be used to direct the tailings to their point of discharge. These pipes would be made of high-density polyethylene



BLOSSOM RIVER
WILSON RIVER
EXISTING MINE ACCESS ROAD (FOR CONTINUATION SEE SH. 8)
BLOSSOM RIVER WATER INTAKE, PUMPING STATION & ACCESS ROAD
WETLANDS AREA
N
UNNAMED CREEK
CULVERT
TURNOUT
99+50
WATER BOOSTER PUMPING PLANT
25' WIDE MINE ACCESS ROAD (INITIALLY UTILIZE EXISTING 14' WIDE ROAD)
TIDE FLATS
TUNNEL CREEK PLANT SITE
PERSONNEL HOUSING
59+00
HTL+19.4
EXISTING BRIDGES
FUEL OIL STORAGE & PUMPING STATION
TUNNEL CREEK
LOG BRIDGE
27 00
24 00
37+00
PROPOSED BRIDGES (FOR PLANT SITE & PERSONNEL HOUSING ACCESS ROADS)
TAILINGS, WATER, FUEL OIL and TREATED SANITARY EFFLUENT PIPELINES
WASTE WATER OUTFALL
70' WIDE CLEARED CORRIDOR TO PLANTSITE
36' WIDE PLANT ACCESS ROAD
0+00
WILSON ARM
Mixing Chamber
PROPOSED MARINE TERMINAL
SUBMERGED TAILINGS PIPELINE
0 1000 2000
SCALE IN FEET
FLOAT CREEK
TAILINGS OUTFALL
PARTIAL ROADWAY FILL ON TIDELANDS:
PLANT ACCESS ROAD STATIONS 24+00-27+00
MINE ACCESS ROAD STATIONS 59+00-70+50
73+00-83+50
86+50-95+00
98+00-99+50
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QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
TAILINGS PIPELINE TO WILSON ARM
SOURCE BECHTEL DWG. SK-C-203 DATE MAR 84
FIGURE II-10
envirosphere company

TABLE II-5
PRELIMINARY TAILINGS THICKENER EFFLUENT CHARACTERIZATION
LIQUID PHASE

Parameter1/	Approximate Concentration (in micrograms per liter unless otherwise noted)
pH (standard units)2/	8.7
Temperature (°F)3/	51
Total dissolved solids mg/l4/	160
Conductivity (μmho/cm)5/	256
Dissolved oxygen (mg/l)5/	7
Total organic carbon (mg/l) 5/ 6/	13
Arsenic7/	6.8
Cadmium7/	15
Chromium7/	34
Copper7/	35
Iron7/	1790
Lead7/	120
Manganese7/	330
Mercury7/	1.2
Molybdenum7/	1080
Nickel7/	290
Selenium7/	6.6
Silver7/	7
Zinc7/	77

Note: The concentrator would produce about 3,780 tph (80,000 tpd) of solids and 3,700 tph of water from thickener underflow. No further treatment of this stream is planned after possible pH adjustment and flocculation. This characterization does not include washdown water, power plant wastewater, adit drainage water, runoff or others.

1/ Prior to transport and mixing with seawater.

2/ pH value is from Bulk Sample Pilot Plant testing without lime addition (hourly tests for four days).

3/ Temperature is an engineering estimate of the tailings before mixing with seawater.

4/ Total dissolved solids was calculated from conductivity, based on 16 analyses of conductivity.

5/ Conductivity, dissolved oxygen, and total organic carbon values are from Bulk Sample Pilot Plant testing from October 24-27, 1983. Dissolved oxygen based on 16 analyses.

6/ Total organic carbon is the parameter which indicates the amount of residual reagents. Value based on three analyses.

7/ From analyses of the tailings samples from Bulk Sample Pilot Plant flotation testing from October 24 to 27, 1983. Number of samples for each parameter are As (32), Cd (32), Cr (29), Cu (53), Fe (17), Pb (32), Hg (32), Mo (32), Mn (19), Ni (32), Se (32), Ag (32), Ni (32).

Source: U.S. Borax 1984a with modifications by Stine 1984 and U.S. Borax 1984d.

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TABLE II-6
PRELIMINARY TAILINGS THICKENER EFFLUENT CHARACTERIZATION
SOLID PHASE

Component	Tailings Concentration Weight Percent 1/
Chemical Balance	
Silicon dioxide (SiO_2)	77.0
Aluminum oxide (Al_2O_3)	11.4
Iron (total) (Fe)	1.2
Magnesium oxide (MgO)	0.3
Calcium oxide (CaO)	0.5
Sodium oxide (Na_2O)	3.2
Potassium oxide (K_2O)	5.0
Carbon dioxide (CO_2)	0.4
Others [TiO_2 (titanium dioxide), P_2O_5 (phosphorus pentoxide), MnO_2 (manganese dioxide), and H_2O (water)]	0.5
	100.0
Mineral Balance	
Quartz	34
Feldspar (total)	60
Biotite	2
Chlorite	1
Molybdenite	0.02
Pyrite	1
Magnetite	0.7
Calcite	0.8
Others	0.48
	100.00

1/ Typical weight percents are from nine whole rock analyses and these mineralogical/chemical analyses of tailings samples.

Source: U.S. Borax 1984a with modifications by Stine 1984.

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TABLE II-7

CONCENTRATOR TAILINGS CHARACTERIZATION
SOLID PHASE, MINOR ELEMENTS

Element	Concentration[1/] (ppm)
Arsenic	10.9
Cadmium	2.4
Chromium	10
Copper	69
Lead	47
Mercury	0.05
Molybdenum	120
Manganese	462
Nickel	17.7
Selenium	0.10
Silver	0.13
Zinc	46

1/ From analysis of the tailings samples from Bulk Sample Pilot Plant flotation testing from October 24-27, 1983. Concentrations are based on one 24-hour composite analyis, ten one-hour composite analyses, and about four grab sample analyses.

Source: U.S. Borax 1984d.

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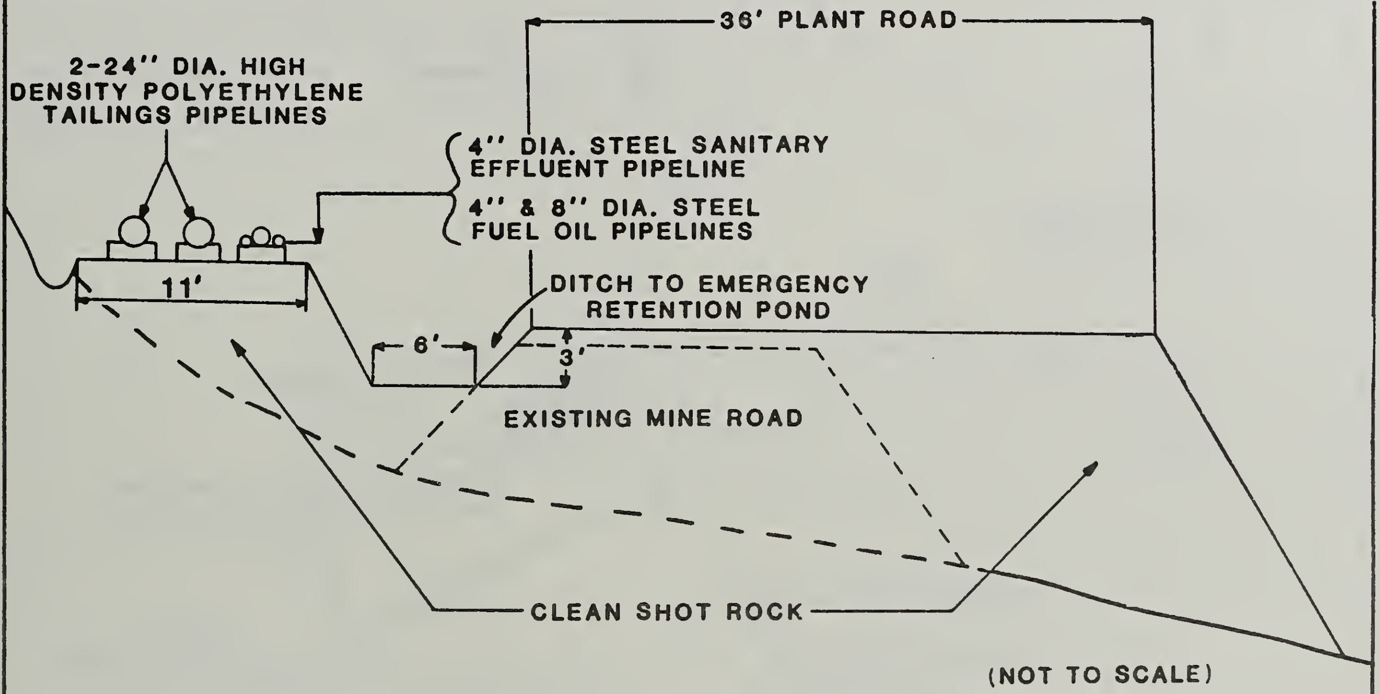
and have 24-in. diameters. The pipelines would follow the Tunnel Creek mill access road, which would be located along the southern slope of the Tunnel Creek watershed (Figure II-10). This access road would be widened to accommodate a raised berm, upon which the parallel pipelines would be secured (Figure II-11). The length of this pipeline system running between the Tunnel Creek mill and the wharf area would be approximately 14,000 ft.

Tailings would be transported from the wharf area to the disposal outfall in Wilson Arm by extensions of the two parallel 24-ft pipelines, which would run an additional linear distance of approximately 3,000 ft. Immediately down-fjord from the wharf area the tailings would enter a dropbox to dissipate energy associated with the hydraulic head in the descending pipelines. A mixing chamber anchored to the side of the fjord below the low tide line would receive the tailings (Figure II-12). Here the tailings would be mixed with seawater in ratios of from 1:1 to 1:4 (tailings:seawater). This tailings-seawater slurry would then flow downward through a submarine pipeline along the fjord bottom to a depth of about 150 ft, where it would be discharged at the location shown in Figure II-13.

The main purposes of the mixing chamber are to eliminate air and provide for a density adjustment of the tailings composition. The mixing of seawater would reduce the specific gravity of the tailings slurry and increase the specific gravity of the liquid fraction to nearer that of seawater in order to minimize turbulence that might interfere with the settling of tailings, and to prevent gravity separation of the liquid fraction in the receiving seawater. The mixing chamber intake would be placed below low tide elevation and would be equipped with screens to discourage entrainment of fish, fish larvae, and plankton. Seawater would be drawn into the submerged mixing box at a rate of 33,000-132,000 gpm. The design intake water maximum velocity would be 0.5 feet per second (fps). The deposited dry density of tailings have been estimated to be 100 pounds per cubic foot based on tests of pilot plant samples. The predominant minerals in the tailings would be quartz and other silicate minerals such as feldspars. Detailed discussions about the deposition of mill tailing on the floor of Wilson Arm are provided in Section 4.1.6.5.

The tailings would have a pH in the range of 8.0 to 9.0, with a likely range of 8.5 to 9.0. The temperature of tailings mixed with seawater would range from 48°F to 51°F in the winter and 55°F to 60°F in summer. The size distribution of the tailings is shown in Table II-8 and Figure II-14. All washdown and general mill area drainage, a portion of the reagents, and treated and sanitary sewage from the Tunnel Creek area would be disposed in the tailings streams. The addition of polyacrylamide (a standard flocculating agent) and pH adjustment at the tailings thickeners may be used to improve the settling characteristics of the tailings. The additional quantities of flocculant and lime are not included in the reagent usage in Table II-4.



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TAILINGS PIPELINE
BERM

SOURCE U.S. Borax DATE Nov 1987

FIGURE II-11

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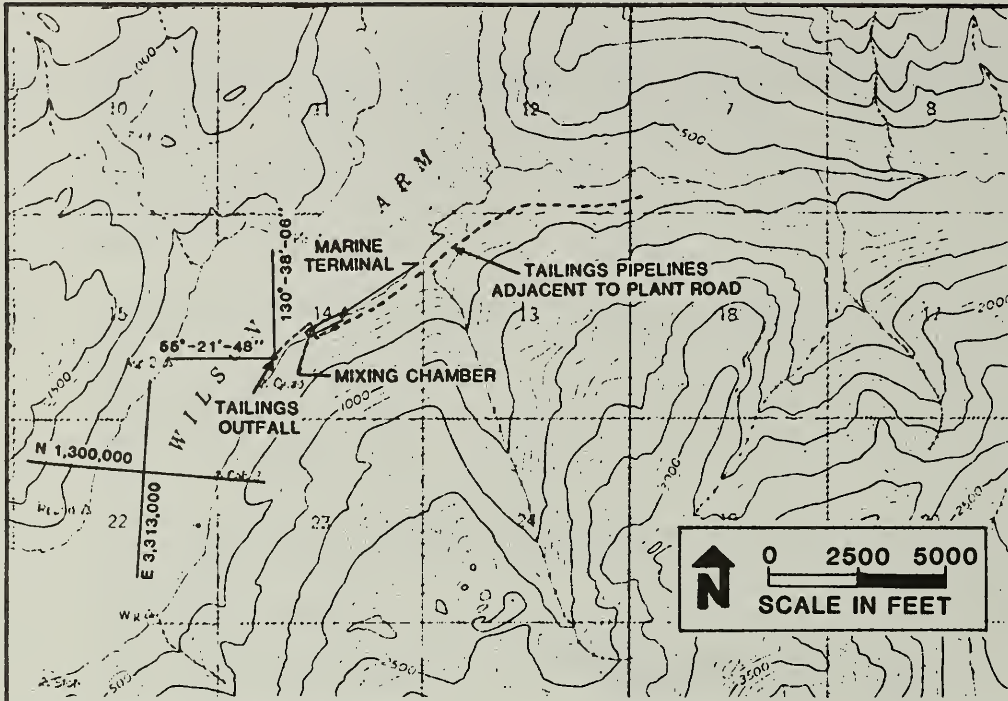
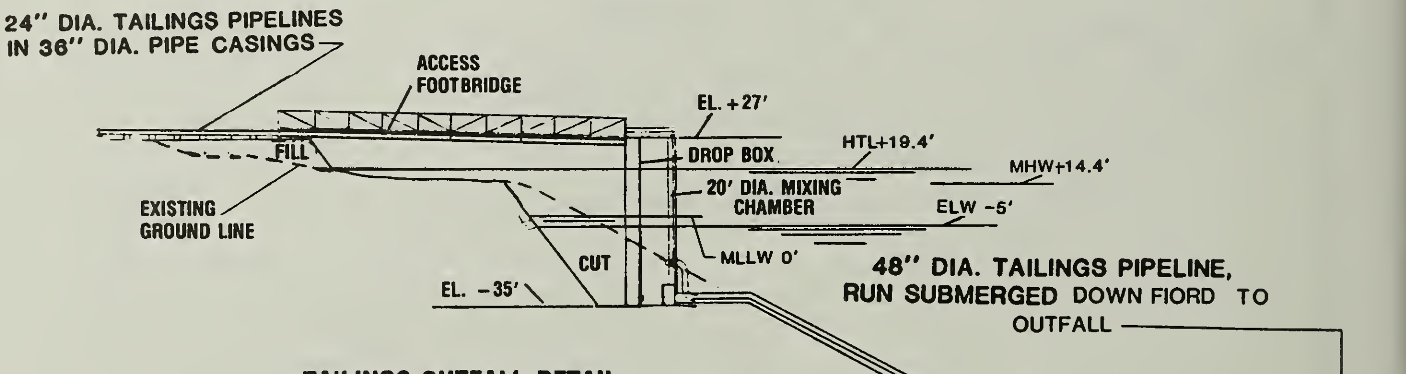


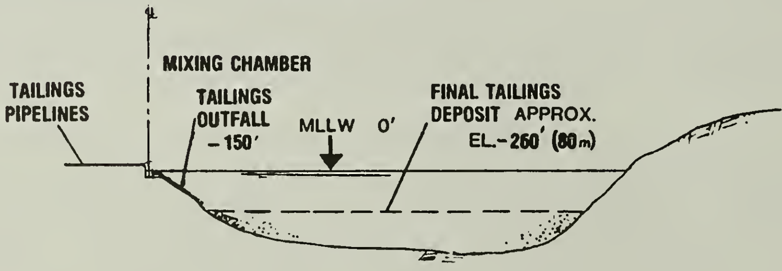
WILSON ARM TIDAL DATA

HIGH TIDE LINE (HTL)	+19.4'
MEAN HIGH WATER (MHW)	+14.4'
MEAN SEA LEVEL (MSL)	+ 8.0'
MEAN LOWER LOW WATER (MLLW)	0.0'
EXTREME LOW WATER (ELW)	-5.0'



TAILINGS OUTFALL DETAIL

0 50 100
SCALE IN FEET



PROFILE OF TAILINGS OUTFALL

0 1000 2000
SCALE IN FEET

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TAILINGS DISPOSAL
MIXING CHAMBER

SOURCE U.S. Borax DATE Nov 1987

FIGURE II-12

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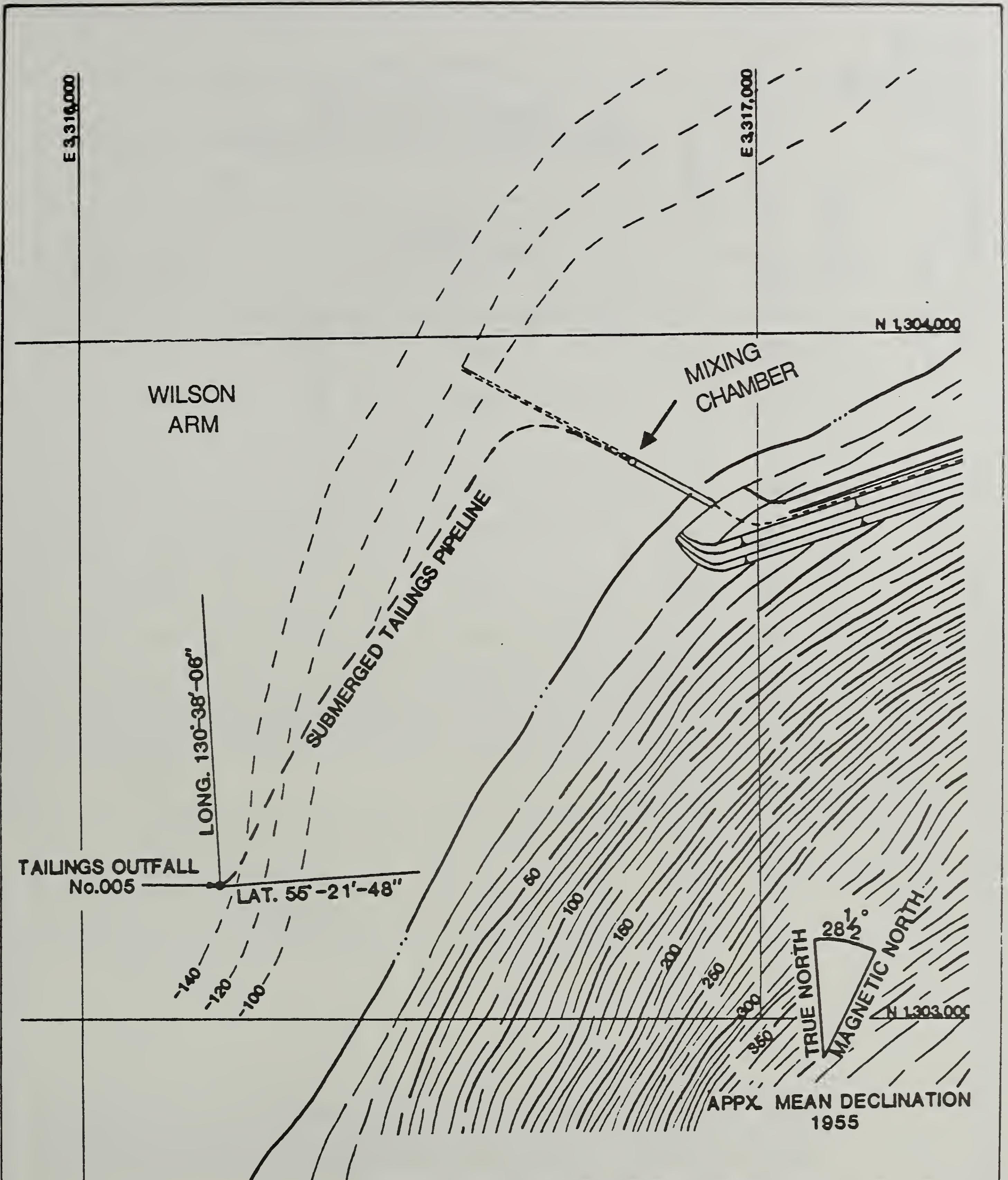


U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE QUARTZ HILL MOLYBDENUM PROJECT MINE DEVELOPMENT EIS	FIGURE II-13
LOCATION OF WILSON ARM TAILINGS DISPOSAL OUTFALL	envirosphere company A Division of EBASCO SERVICES INCORPORATED
SOURCE U.S. Borax DATE Nov 1987	

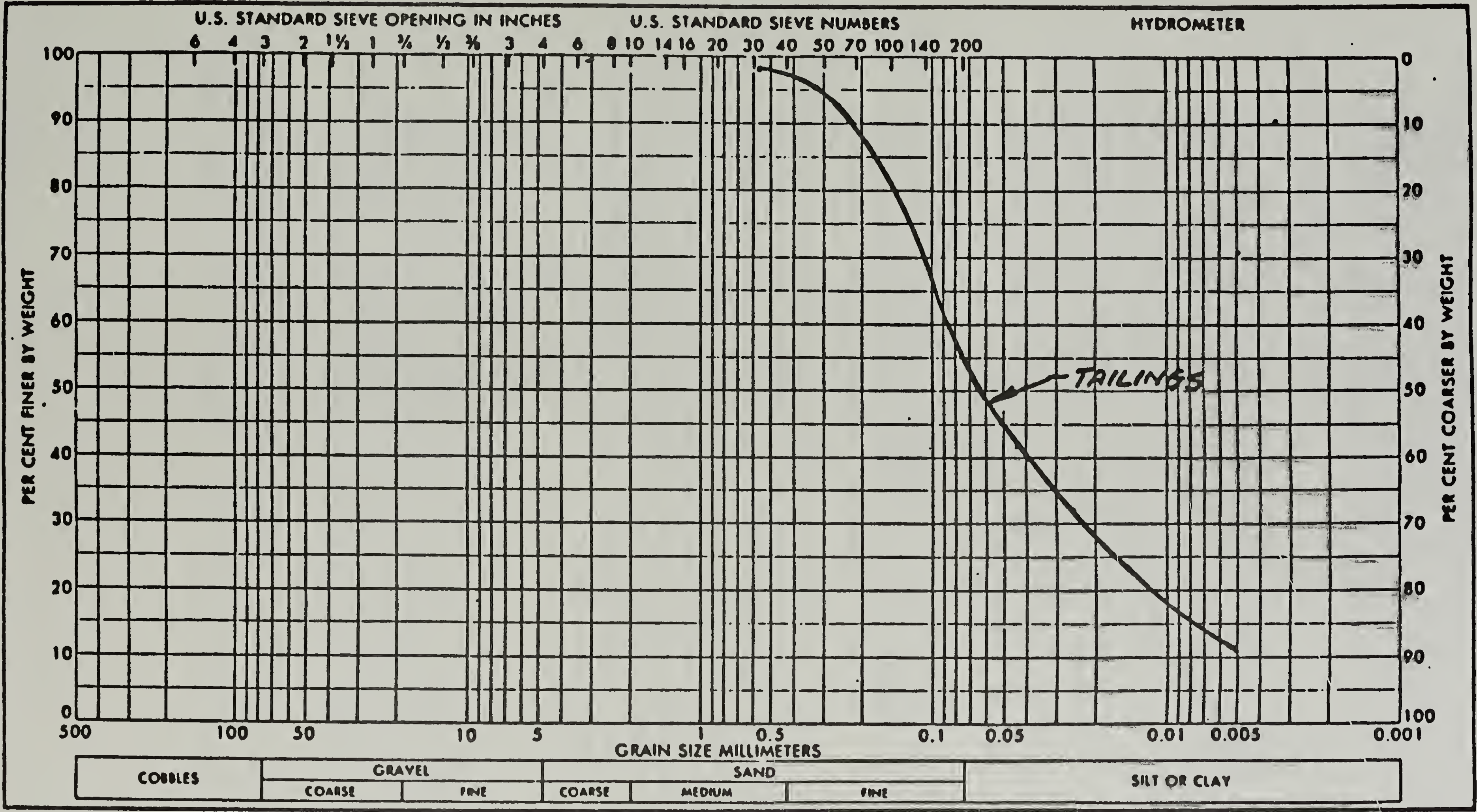
TABLE II-8

CONCENTRATOR EFFLUENT
TAILINGS PARTICLE SIZE DISTRIBUTION

Upper Limits, Microns	U.S. Standard Sieve Equivalent No.	Weight Percent Passing 1/
595	28	98.8
297	48	95.1
210	65	90.0
149	100	80.9
105	150	69.4
74	200	53.0
53	270	46.3
44	325	42.4
37	400	38.9
30	-	35.2
25	-	32.4
20	-	28.5
15	-	23.4
10	-	18.0
5	-	10.7

1/ From analyses of samples from the Bulk Sample Pilot Plant grinding tests on October 14, 15, and 18, November 30, December 1 and 19, 1983 (six tests). The grinding target for the concentrator is 20 percent plus 100 mesh (149 microns).

Source: U.S. Borax 1984a.



U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE QUARTZ HILL MOLYBDENUM PROJECT MINE DEVELOPMENT EIS	FIGURE II-14
TAILINGS SOLID PHASE PARTICLE SIZE DISTRIBUTION	envirosphere company A Division of EBASCO SERVICES INCORPORATED
SOURCE U.S. BORAX DATE FEB 84	

The entire tailings pipeline system would undergo periodic inspection for wear and integrity. Past experience with wear in mill tailings pipelines made of high-density polyethylene indicate an expected lifetime of about 10 years. A monitoring schedule would be determined from intensive early testing to establish wear characteristics. All worn pipe sections would be rotated or replaced based on detection of significant weakness. Periodic monitoring would be conducted using ultrasonic equipment, and pressure sensitive instruments would be used for continuous monitoring of internal hydrostatic pressure. The detection of sudden pressure changes within these pipelines would trigger an electronic alarm at the mill site and discharge from the thickeners would be stopped almost immediately. The mill could continue to operate at reduced capacity using only one of the two parallel pipelines until the condition is remedied. If both pipelines should develop leaks simultaneously, all valves at the discharge of thickeners would be closed. Passive monitoring by mine personnel would also occur continuously as they travel the access road from the wharf area to the Tunnel Creek mill site. Pipeline ruptures would be immediately obvious to anyone using this road.

The pipeline monitoring and rotation program should be adequate to prevent the occurrence of leaks or ruptures. However, additional steps would be taken to contain a tailings spill in the unlikely event of a pipeline rupture. Emergency trenches and holding ponds would be constructed at the time the access road is developed. These would be large enough to contain a spill of 5,000 cu yd of tailings, or about 500 cu yd greater than the maximum spill expected from a pipeline rupture given a response time of 30 minutes (see scenario number 7 in Table 16-1, Appendix G). A trapezoidal channel with a 6-ft base width and 3-ft depth would be constructed between the road and the pipeline to act as an emergency catch trench (Figure II-11). This trench would lead to holding ponds located either in the Tunnel Creek watershed or near the wharf area, depending upon specific terrain conditions and the final design of the access road. Trenches would be routinely maintained to keep them free of clogging debris. Pipeline sections that cannot be accommodated by parallel trenches would be enclosed in larger pipes to contain tailings spills, which would include the section crossing Tunnel Creek and the submerged section running along Wilson Arm from the wharf area to the disposal site (Figure II-10). The emergency enclosure pipe guarding the section crossing Tunnel Creek would empty into the parallel trench located on the southern slope of its watershed. The emergency pipes enclosing sections running along Wilson Arm would empty into the mixing chamber at the point of discharge.

For the discharge pipe, wear is much less for the underwater portion of the pipe than for the on-land portion. Also, the pipe will be replaced for the underwater portion rather than rotated as will be done above water.

Reclamation of the tailings disposal facilities at mine closure would be accomplished by recontouring, reseeding, and replanting of the surface pipeline areas. All pipeline and facilities installed in Wilson Arm would be removed and salvaged.

F. HOUSING FACILITIES

Employee housing and services during construction and operation would be provided in a phased development schedule corresponding to the development of the mining project. To the extent it would be available, single status employee housing for the operations workforce would be initially utilized by construction personnel. However, because the construction workforce would be larger than that for operations, additional accommodations would have to be provided during construction. This excess construction accommodation would be temporary facilities to be removed after the construction period. Preliminary estimates of the workforce required during the development of the project are presented in Table II-9. During the first year of project construction (preproduction phase) a limited number of construction workers would be at the project site during the winter months. As buildings are completed, winter construction activities would proceed utilizing the building interiors for shelter. Single status housing would be used in conjunction with commuting from Ketchikan during the operations phase.

During the construction phase, personnel would be housed at the project sites on a full time basis. They would be transported by ferry and floatplane on a contract basis from Ketchikan to the project site. Personnel would be transported back to Ketchikan upon termination or for vacations. About 70 persons per week would be transported at peak workforce. Although recreational facilities would be provided at the construction camps, it is expected that there would be trips once a week to Ketchikan for one day visits (6-10 hour day/work week). On the average, about 100-200 persons would be transported on weekends.

1. Construction Camps

Temporary construction camps would be of two types. A floating construction camp would be located at the Wilson Arm wharf, and land based construction camps would be located at the Tunnel Creek mill site and at the Quartz Hill mine site. As construction phases are completed, the temporary land based camps and the floating camp would be removed. Some of the construction workers would be housed in permanent single status housing designed for the operations workforce. Approximately 40 staff family housing units would be provided for construction staff. This housing would be rehabilitated as needed to accommodate the operational workforce.

TABLE II-9

WORKFORCE FOR QUARTZ HILL PROJECT

Year	Quarter	Construction[1/]	Quartz Hill Operations	Ketchikan Office	Total
Preproduction					
-4	4	80			80
-3	1	80		10	90
	2	90		10	100
	3	200		10	210
	4	470		10	480
-2	1	830	10	10	850
	2	1050	70	10	1130
	3	1150	90	10	1250
	4	1170	90	10	1270
-1	1	1150	90	10	1250
	2	1020	130	10	1160
	3	690	180	10	880
	4	140	380	30	550
Startup					
1	1	50	550	80	680
	2	10	610	80	700
	3		630	80	710
	4		630	80	710
2	1		710	80	790
	2		710	80	790
	3		710	80	790
	4		710	80	790
3	1		710	80	790
	2		710	80	790
	3		710	80	790
	4	20	710	80	810
4	1	140	730	80	950
	2	260	730	80	1070
	3	300	750	80	1130
	4	160	830	80	1070

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TABLE II-9 (Cont'd)

WORKFORCE FOR QUARTZ HILL PROJECT

Year/Quarter		Construction 1/	Quartz Hill Operations	Ketchikan Office	Total
Expansion to 80,000 tpd					
5	1	30	850	80	960
	2		870	80	950
	3		870	80	950
	4		900	80	980
6			900	80	980
7			910	80	990
8			900	80	980
9			900	80	980
10-13			910	80	990
14-16			920	80	1000
17-19			930	80	1010
20 2/			940	80	1020

1/ Includes subcontractors such as camp catering and housekeeping.

2/ After year 20 the number of workers at the Quartz Hill site may increase gradually due to increased labor needs at the open pit operation caused by increasing haul distances to the crusher and waste rock area as the pit deepens and increases in size and as the waste rock area expands.

Source: Schlessinger 1984.

Wilson Arm Floating Camp

This camp would house approximately 200 to 250 personnel for the following project activities:

- Construction of the access road from the mouth of Tunnel Creek to the concentrator site in upper Tunnel Creek and upgrading the existing mine access road;
- Earth removal activities at the coarse ore conveyor;
- Site preparation and construction of the land based Tunnel Creek and Beaver Creek housing facilities;
- Initiation of construction of the coarse ore conveyor;
- Construction of Wilson Arm wharf and dock facilities.

The floating camp would be operated from commencement of construction through completion of the land based housing facilities, a duration of approximately 8 to 12 months. The camp would be approximately 250 ft by 80 ft and be self contained with no land based facilities except a structure for potable water drawn from a nearby unnamed creek and an incinerated refuse burial area at an approved location. The camp would be moored in deep water just offshore of the existing wharf. Additional barges for shop space, fuel storage and equipment transfer would be provided as needed until these facilities are established on land. A stiff-leg boom would be provided as needed for rafting timber during construction. The stiff-leg boom would be approximately 600 ft long and would be moored adjacent to the floating camp in water of a depth sufficient to prevent grounding at low tide.

The camp would be owned and operated by the contractor selected for initial construction activities. The contractor would provide space for the required U.S. Borax and contractor personnel until completion of the land based housing facilities at Tunnel Creek and Beaver Creek.

Tunnel Creek Camp and Housing Facilities

These facilities would house the 900 personnel required for the construction of all facilities in the Tunnel Creek area and an additional 150 staff and visitors.

Initial occupancy would take place 9 to 12 months after the start of project construction. After completion of millsite construction, the housing facilities would be refurbished for its permanent use by a maximum of 240 operating phase personnel on single status, including "stayovers" and guests. These housing facilities would operate throughout the life of the mine. Surplus facilities built specifically to accommodate construction phase needs would be removed.

The housing facilities would be located west of the mill site (Figure II-1) and would disturb approximately 6 acres. It would be of modular design and would include sleeping quarters, kitchen, dining, and recreation facilities. Potable water for the camp would be drawn from Tunnel Creek or tributary. Sewage would be treated in a temporary secondary treatment facility and discharged to Tunnel Creek until permanent facilities are constructed. Effluent discharge from the permanent facility would be to the tailings line. Runoff from the site would be collected in the Tunnel Creek sedimentation pond. Solid waste would be incinerated and the ash buried at an approved location. During operations, burned refuse would be disposed with the excavated waste rock. Temporary diesel generators would provide electricity until the main power plant is on-line.

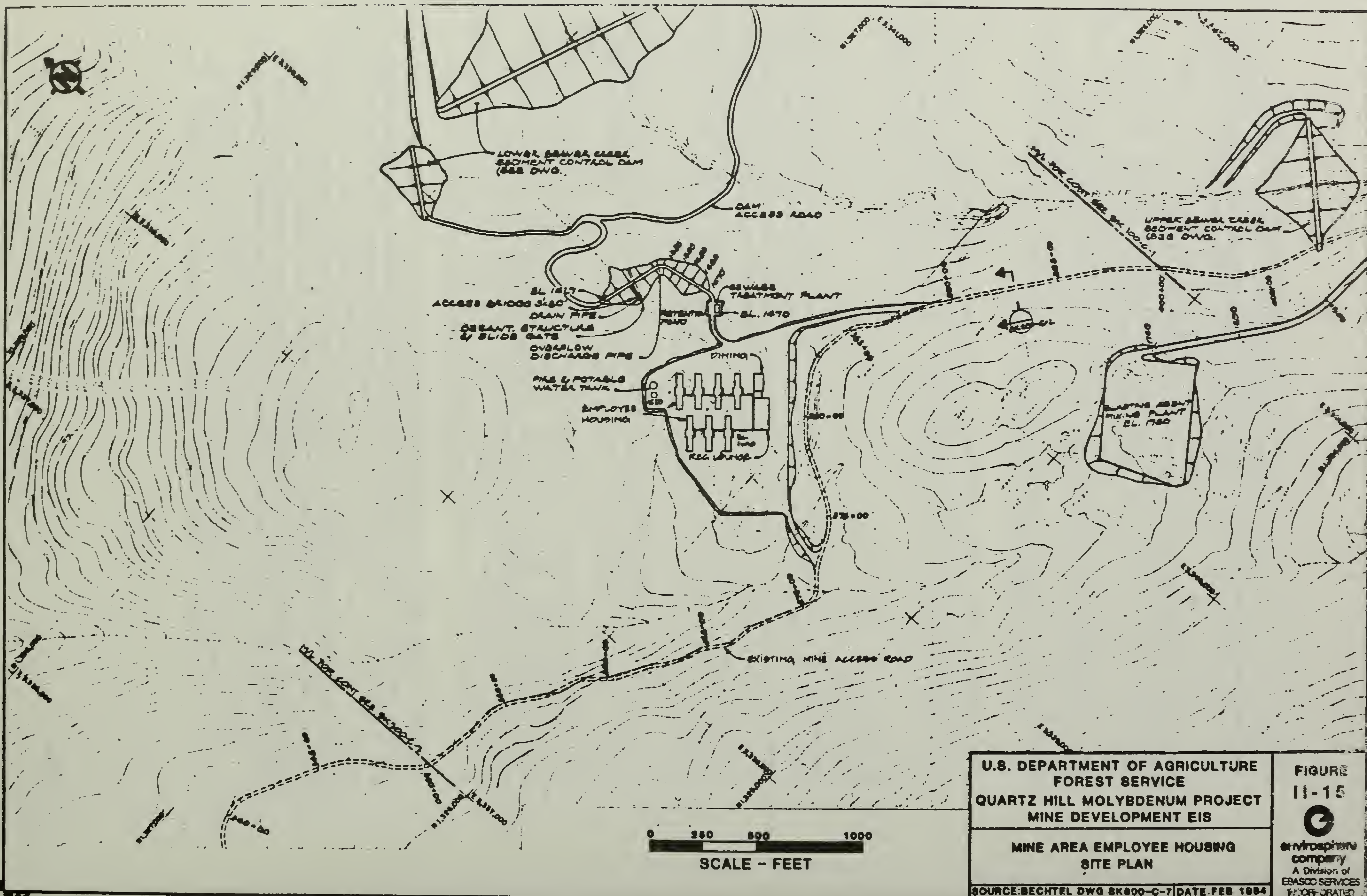
The housing facilities would be project owned and operated. Actual operations would be contracted to a professional camp catering service and supervised by U.S. Borax personnel. At the end of the mine life, the facilities would be removed and the area recontoured and reseeded.

Beaver Creek Camp and Housing Facilities

Located near the mine east of Bruce's Nose, about one mile west of the mine service area, the Beaver Creek camp and housing facilities would accommodate approximately 400 personnel required for the construction of all mine facilities and for mine preproduction phase activities. The developed area of the camp would result in the disturbance of about 16 acres for a level pad approximately 1,000 ft by 700 ft, requiring 9,000 cu yd of rockfill material, as shown in Figure II-15.

The permanent accommodations would be designed for its ultimate purpose of housing operating personnel, but would be used as appropriate for housing construction workers during the construction phase. The camp would be occupied 4 to 6 months after the start of construction and would be used throughout the life of the mine. After completion of mine construction, the camp would be refurbished for the operating workforce for a maximum of 330 occupants, including operating personnel, "stayovers" and guests. Any surplus facilities constructed specifically for construction personnel would be removed.

The facilities would be of modular design and would include sleeping, dining, kitchen and recreation facilities. Temporary potable water, waste disposal, and power generation facilities would be located nearby. Water for the camp would be obtained from a diversion dam that would be constructed on No. 1 Creek. The diversion dam will require the placement of approximately 200 cu yd of clean shot rock fill of which approximately 50 cu yd would be below the ordinary high water mark (OHWM) and approximately 150 cu yd in the adjacent wetlands. The



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MINE DEVELOPMENT EIS

FIGURE II-15

MINE AREA EMPLOYEE HOUSING SITE PLAN

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SOURCE: BECHTEL DWG SK800-C-7 | DATE: FEB 1984

size of the impoundment would be approximately 0.1 ac. Site runoff from the housing area would be directed to a sedimentation pond. The retention pond would be designed to contain the equivalent volume of runoff generated by the 10-year, 24-hour storm event. Sewage effluent would be discharged to a sanitary drain field. Solid waste would be incinerated and the ash buried at an approved location. Diesel generators would provide electricity during construction until the main power plant is completed.

The housing facilities would be project owned and its operations would be contracted to a professional catering service. At the end of the mine life, the facilities would be removed and the area recontoured and reseeded.

2. Operational Workforce

During project operation, workers would commute from Ketchikan to the project site where they would be housed in the facilities described above. Shift scheduling during mine operations is planned as a 7-day on, 7-day off 12-hour shift for all hourly employees. Salaried employees would work 5-hour days on Monday and Friday and 10-hour days from Tuesday to Thursday.

A 150-passenger high speed ferry would be used to transport personnel between Ketchikan and the project site. A standby vessel of 75-passenger capacity would be available for emergency use. Travel time would be about 2 hours, 30 minutes, one way not including loading and unloading. Hourly employees would work on a staggered shift schedule with three groupings of about 250 to 300 persons each. Groups of about 100 to 150 persons would be changed over on Tuesday, Wednesday, and Thursday. Approximately 100 salaried personnel would be transported from Ketchikan to the mine site on Mondays and would return to Ketchikan on Fridays. Travel would be around noon. The ferries would operate between 9:30 a.m. and 2:30 p.m. to assure daylight operation during the winter months. If the ferries cannot operate for any reason on a scheduled trip, workers at the site would continue to operate the mine and mill until the relief employees can be transported to the site.

Float planes and helicopters would be available for emergency transportation between Ketchikan and the project site. An average of 4 float plane round trips per day and about 20 hours per week of helicopter travel would be anticipated.

Docking in the Ketchikan area would be either at leased, existing facilities or at new docks constructed for the project. No further details on dock facilities are currently available; however, possible existing sites include the Saxman Seaport, Spruce Mill Maintenance Facility, South Coast Construction, Wayne Construction, and Seaward Shipyard.

G. OTHER SUPPORT FACILITIES

1. Wilson Arm Wharf

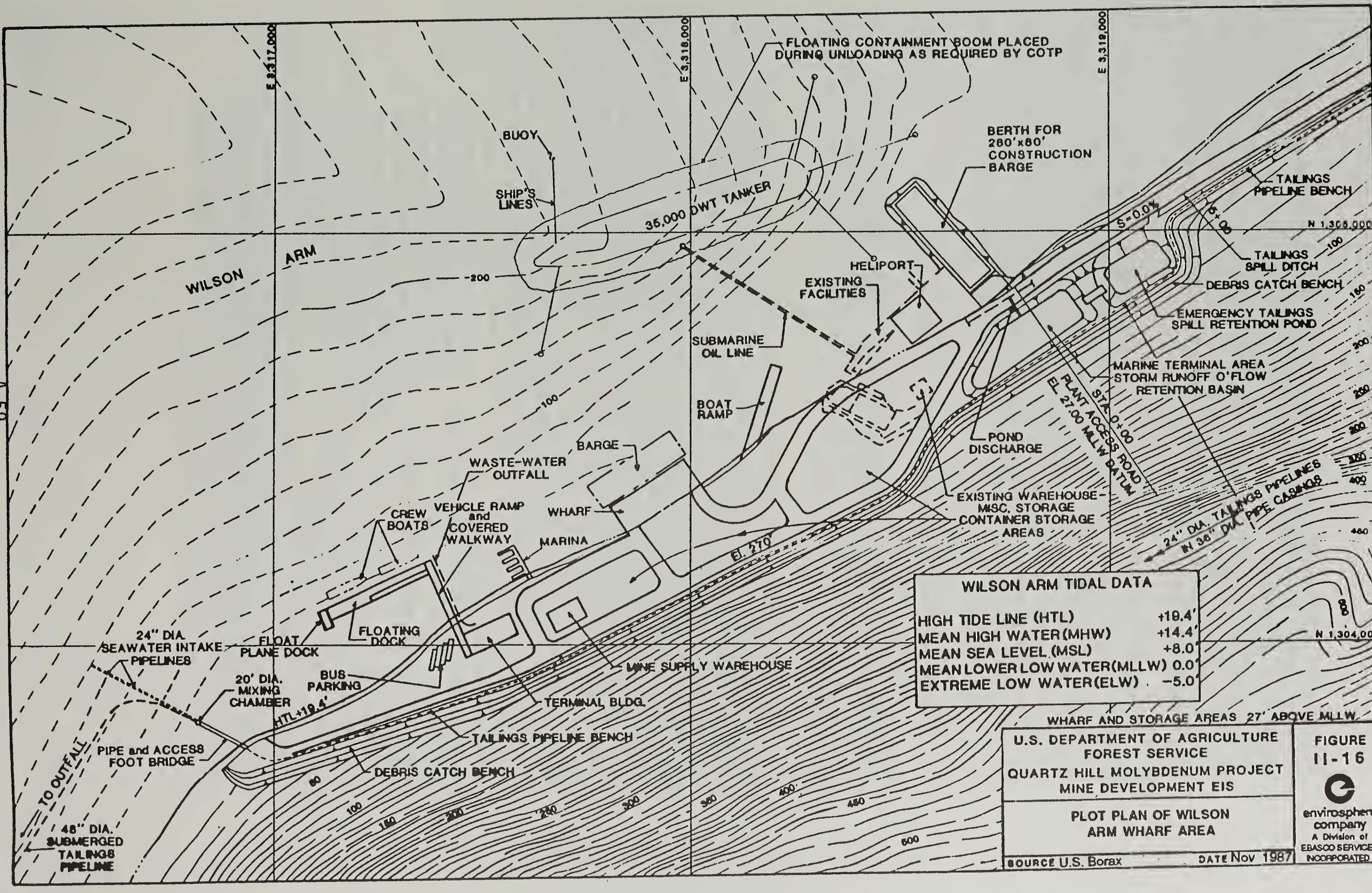
The existing wharf and associated facilities at Wilson Arm would be expanded to approximately 10 ac and would occupy approximately 2,500 ft of shoreline. The direction of expansion would be primarily south along Wilson Arm from the existing wharf area (Figure II-16). In addition, tanks for diesel and fuel oil would be located about 3,500 ft north along the road to the mill.

The wharf facilities would include a mine supply warehouse, terminal building, heliport receiving facilities, shuttle and crew boat docking facilities, floating marina, seaplane float, barge dock, tanker unloading facilities for fuel oil, fuel storage tanks, spill control facilities, sewage treatment plant, heliport, vehicle parking area, and maintenance facilities. Mooring and two submarine pipes and hoses would be provided for a 35,000 dead weight tons (DWT) tanker.

The barge wharf would be 220 feet long by 60 foot wide with a concrete deck supported by piles anchored into rock. The floating dock would be 250 feet long by 20 feet wide and would be accessed by a 15 feet wide piled trestle. This trestle would also carry the treated wastewater effluent pipeline which would discharge below the water surface at approximately minus 20 feet MLLW.

The wastewater and sewage from the wharf would pass through a small package secondary treatment plant at the wharf. The wastewater discharge at the wharf would include treated equipment washdown water from the fuel oil storage area and marine terminal facility and treated sanitary sewage from the marine terminal and facilities at Tunnel Creek, and site runoff from the terminal area. Equipment washdown water would be treated in a conventional oil/water separator and sanitary sewage will be treated in a package activated sludge treatment plant. A stormwater retention pond will be provided to provide settling time for area runoff prior to discharge. Total discharge at the wharf outfall would be approximately 130,000 gpd. Potable water would be supplied by the mill freshwater system.

The facility would require construction of a barge berth near deep water and land adjacent to the shore to create the storage area. The berth for construction barges would involve placement of approximately 12,000 cu yd of rockfill material below the high tide line elevation in the area shown for this facility in Figure II-16. Construction of the wharf area would require further blasting and removal of rock. The on-shore storage and cargo laydown area would be excavated, leveled and surfaced with gravel to elevation 27 ft above MLLW. Approximately 330,000 cu yd of excavated material would be moved. This other excavated material would be used to raise and widen the existing mine


FLOATING CONTAINMENT BOOM PLACED DURING UNLOADING AS REQUIRED BY COTP
BERTH FOR 260'x80' CONSTRUCTION BARGE
TAILINGS PIPELINE BENCH
TAILINGS SPILL DITCH
DEBRIS CATCH BENCH
EMERGENCY TAILINGS SPILL RETENTION POND
MARINE TERMINAL AREA STORM RUNOFF O'FLOW RETENTION BASIN
STA. 0+00
PLANT ACCESS ROAD EL 27.00 MLLW DATUM
POND DISCHARGE
EXISTING WAREHOUSE-MISC. STORAGE CONTAINER STORAGE AREAS
24" DIA. TAILINGS PIPELINES IN 36" DIA. PIPE CASINGS
BUOY
SHIP'S LINES
35,000 DWT TANKER
WILSON ARM
HELIPORT
EXISTING FACILITIES
SUBMARINE OIL LINE
BOAT RAMP
BARGE
WASTE-WATER OUTFALL
VEHICLE RAMP and COVERED WALKWAY
CREW BOATS
WHARF
MARINA
EL 270
FLOATING DOCK
FLOAT PLANE DOCK
24" DIA. SEAWATER INTAKE PIPELINES
20' DIA. MIXING CHAMBER
BUS PARKING
HTL +19.4'
MINE SUPPLY WAREHOUSE
TERMINAL BLDG.
TAILINGS PIPELINE BENCH
DEBRIS CATCH BENCH
PIPE and ACCESS FOOT BRIDGE
TO OUTFALL
48" DIA. SUBMERGED TAILINGS PIPELINE
E 3,317,000
E 3,318,000
E 3,319,000
N 1,305,000
N 1,304,000
S=0.0%
5+00
WILSON ARM TIDAL DATA
HIGH TIDE LINE (HTL) +19.4'
MEAN HIGH WATER (MHW) +14.4'
MEAN SEA LEVEL (MSL) +8.0'
MEAN LOWER LOW WATER (MLLW) 0.0'
EXTREME LOW WATER (ELW) -5.0'
WHARF AND STORAGE AREAS 27' ABOVE MLLW
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT MINE DEVELOPMENT EIS
PLOT PLAN OF WILSON ARM WHARF AREA
SOURCE U.S. Borax
DATE Nov 1987
FIGURE II-16
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access road in the tidal area. Approximately 50,000 cu yd of this fill material would be placed below the high tide line. Excess material would be disposed of in the waste rock pile at the processing plant. Major earthwork and construction of the barge wharf and boat dock would be by a crew living in the Wilson Arm floating camp. Sediment and runoff control would be provided during construction and operation by a storm water retention pond.

The Wilson Arm wharf would be the key access point during both construction and operation for all mine personnel, equipment, materials, and supplies, and for shipping the molybdenum concentrate. Reagents and fuel would be handled and stored using strict spill control procedures. Adequate snow and ice control would be provided. Snow would be removed by snowplows and dumped directly into Wilson Arm. Navigation channels in the fjord would be kept ice free by operating tugs and barges.

2. Mine Development Road and Access Roads

Permanent roads would be needed from the marine terminal to the concentrator plant site on Tunnel Creek, to the supplemental water supply facilities adjacent to the Blossom River, and to the mine site at Quartz Hill.

The mine development road would generally follow the alignment of the bulk sample access road (Figure II-1). The portion over tideland would be widened and raised to avoid flooding at extremely high tides. Approximately 50,000 cubic yards of clean shot rock would be placed on tidelands. Approximately 5,000 cubic yards would be between the wharf and the plant access road with the remainder further up-fjord. Of the 45,000 cu yd of fill used on the up-fjord sections, approximately 1,500 cu yd of this amount will be used for turnouts. The existing nominal roadbed width of 14 ft would be replaced by a roadbed 36 ft wide (28 ft road with 4 ft shoulders). Maximum grades would be 6 percent; the road surface would be graveled. The abutments for the existing bridges constructed over Tunnel Creek and South Tunnel Creek for the access road for bulk sampling were installed to meet the requirements of the permanent mine development road. The bridge stringers and deck for the second road lane would be installed. Minimal instream work would be required at these crossings. Other bridges constructed for bulk sampling access would be upgraded, as required. Instream work and placement of fill material would be required to upgrade stream crossings at No. 3 Creek, No. 1 Creek and Raspberry Creek. Sediment would be controlled by installing runoff and drainage diversion structures and by revegetation of cut slopes by hydroseeding with a mulch and grass seed mixture or using fiber mats. Fill material would be excavated from several quarry areas adjacent to the road. Materials unsuitable for use in road construction would be placed in waste disposal areas. Snow would be removed by snowplows. During dry conditions, dust would be controlled by watering. Road surface maintenance would be performed as required.

The access road to the Tunnel Creek valley processing plant and other nearby facilities would be Forest Service Class A, 36 ft wide roadbed including shoulders, with a cleared right-of-way 70 ft wide to allow access for large preassembled modules. The gravel road would follow the route shown in Figure II-I. The road would cross Tunnel Creek at two points approximately 4,500 and 7,000 ft from its mouth. The upstream crossing to the concentrator would be 32 ft wide, while the downstream crossing to employee housing would be 14 ft wide. Widening of the existing bulk sample access road would involve placement of 5,000 cu yd of clean shot rock, from the marine terminal excavation, on tidelands in a 2,000 ft stretch from the terminal northward. The bridge abutments for these crossings would entail placement of approximately 30,000 cu yd of fill below the ordinary high water mark of Tunnel Creek. Streams would be crossed by culverts or bridges. Additional culverts would be installed along the roadbed as needed to allow necessary drainage. Fill material would be obtained from the processing plant or tunnel construction areas or would be excavated from quarry areas adjacent to the road. Snow from the completed roadway would be removed by snowplows or by hauling to a disposal area. Merchantable timber cleared from the road right-of-way may be used in construction or sold; the remaining noncommercial timber would be placed in a disposal area. Sedimentation would be controlled by installing runoff and drainage control structures and by hydromulching disturbed areas.

The access road to the supplemental water supply facilities on the Blossom River would be 19 ft wide and 3,000 ft long. It would connect with the mine access road near the river confluence. The road would have a gravel surface and probably would not require regular dust or snow control. Merchantable timber cleared from the right-of-way would be sold or utilized on site and noncommercial timber would be placed in a disposal area. Fill materials would be obtained from quarries adjacent to the road or cuts on the final access road.

Measures would be employed during construction and operation of all roads to reduce the environmental impacts. These measures include:

- Using energy dissipators on culvert pipes
- Revegetating disturbed areas, cut banks, side cast materials, as soon as possible
- Seeding and mulching any landslide within 48 hours or as soon as weather conditions allow
- Hauling landslide materials to approved disposal sites
- Constructing brush barriers, check dams, settling basins to capture sediment
- Providing roadside drainage control via ditching etc.
- Constructing culverts for fish passage
- Using special blasting techniques in landslide prone areas, including test shots and avoidance of blasting after heavy rains

- o Designing and constructing roads and stream crossings to minimize encroachment into stream channels, so as not to block fish movement
- o Timing construction to avoid spawning seasons when feasible, i.e., Tunnel Creek bridge crossing work within the wetted perimeter of the stream will occur only between May 15 and July 1
- o Restricting blasting or limiting ground pressures to protect fish.

As the mine pit is developed, haul roads would have to be constructed in the immediate vicinity of the mine to connect the pit with the crusher, waste rock areas, mine services area, and sediment control dams. These roads would be constructed of mine overburden or waste rock, and would shift in time to accommodate additional waste rock and access requirements. These roads would be within the disturbed area boundary of the mine site.

3. Electric Power Supply

Electrical power would be provided during construction by diesel powered generators. These units would be fueled by No. 2 distillate oil.

The proposed electric power generating station for the mine project would be located at Tunnel Creek near the concentrator (see Figure II-9). The power plant as proposed would be a combined cycle gas turbine plant with an initial installed capacity of about 95 MW (including an installed spare turbine). Plant operating capacity would be 60 MW. Initial average demand would be 36-42 MW with a peak demand of 46-49 MW. The plant would probably consist of 2 combustion turbine generators with associated heat recovery steam generators (HRSG) and one steam turbine generator. After 4 to 6 years, a third combustion turbine and associated HRSG would be added in order to bring the total installed capacity to 130 MW and a plant operating capacity of 95 MW. The average load would be 67-80 MW at an ore production rate of a nominal 80,000 tpd with a peak demand of 82-96 MW.

The combined cycle option is generally recognized as highly efficient thermal technology. When operated in a base load mode, it can achieve heat rates of about 9000 Btu/kWh on a higher heating value basis (efficiencies are about 38 percent). Exhaust gas from each combustion turbine, typically at temperatures of about 1000° F, would be ducted to an unfired HRSG producing moderate pressure, superheated steam (e.g. 600 psig and 900°F) which would drive a conventional condensing steam turbine generator. Air filter/silencers would be installed on each gas turbine.

Combined cycle plants can be fueled by natural gas, distillate oil, No. 6 oil, or crude oil. This fuel flexibility is of particular importance given the remoteness of the Quartz Hill location. The fuel proposed for the initial use in the combined cycle plant is No. 2 fuel oil.

Typical oil for the power plant initial operation is expected to be of the following analysis:

Grade	Fuel Oil No. 2
Ash (percent wt)	0.01
API gravity	30
Sulfur (percent wt approx)	0.11 (future supply would be 0.06 percent)
Higher heating value	19,450 Btu/lb

At an ore production rate of 80,000 tpd, it is estimated that approximately 40 million gallons of oil (950,000 bbl) would be required for power generation annually. The fuel would be delivered to Wilson wharf and stored in two 55,000 bbl tanks. The tanks would be located on the uphill side of the access road near the junction of mine and plant access roads. It would be pumped to one 55,000 bbl tank at the power plant. In addition, two 15,000 bbl tanks for diesel oil to serve the mobile equipment would be located at the wharf. The storage tanks would contain a 45 day supply of distillate fuel for the power plant. The tanks would be diked to contain the contents of the tanks plus the displacement volume of the tanks. Fuel pipelines would be suitably valved for spill prevention. The pipeline to the powerplant would be on a berm along the access road. Spills would be contained by a channel between the road and pipeline. The crude and heavy oils, if used, would be treated to remove corrosion-causing impurities (sodium and potassium) by emulsification with water and subsequent electrostatic separation.

Combined cycle combustion turbines operated on light oils or gaseous fuels have low airborne emissions. Particulates from heavy (No. 6) oil combustion, if used, would be controlled to below regulatory limits. Oxides of nitrogen (NO_x) would be controlled by water injection into the combustion turbines, with the steam being exhausted with the products of combustion. If oils with sulfur levels above 0.06 percent sulfur are used to generate more than 50 MW, sulfur dioxide (SO_2) would be controlled by use of limestone scrubbers. Airborne emissions are shown in Table II-10.

About 14,500 gpm of raw water would be used for cooling the steam turbine condenser. The mineral content of water would not be changed while passing through the steam condenser. However, the temperature would rise by about 20° to 40°F. Condenser cooling water would be chlorinated at about 2 week intervals to kill the organic growth if

TABLE II-10
AIRBORNE EMISSIONS

Operations	Uncontrolled (lbs/hr)	Maximum 24-hr (lbs/hr)	Annual Average (tons/yr)
Tunnel Creek Valley			
Power Plant			
PM	N/A	3.6	13.7
SO_2	N/A	31	134
NO_x	N/A	217	955
CO	N/A	67	294
VOC	N/A	24	107
Coarse Ore Stockpile			
Load-in by Conveyor Transfer Point	0.16	0.05	0.21
Wind Erosion	0.1	0.01	0.02
Load-out from Coarse Ore Stockpile	N/A	0.01	0.03
Petroleum Storage Tanks			
Power Plant Fuel			
Breathing Losses	N/A	0.1	0.3
Working Losses	N/A	0.1	0.3
Diesel Fuel Storage			
Breathing Losses	N/A	Neg.	0.1
Working Losses	N/A	Neg.	0.1
Concentrator Access Road			
Fugitive Dust	N/A	0.7	0.3
Tailpipe Emissions			
CO	N/A	0.4	1.8
NO_x	N/A	0.1	0.3
PM	N/A	Neg.	0.1
VOC	N/A	0.1	0.2
Mining Operation Sources			
Drilling of Ore and Waste Rock	0.7	0.5	2.2

TABLE II-10 (Continued)

AIRBORNE EMISSIONS

Operations	Uncontrolled (lbs/hr)	Maximum 24-hr (lbs/hr)	Annual Average (tons/yr)
Mining Operations (Continued)			
Blasting of Ore and Waste Rock	8.5	8.5	37.2
Waste Rock Removal	0.1	0.1	0.1
Waste Rock Haulroad			
Fugitive Dust	905.6	135.8	112.6
Tailpipe Emissions			
NO_x	N/A	806.7	1,032.0
HC	N/A	12.6	16.1
CO	N/A	115.2	147.5
PM	N/A	26.4	33.8
Waste Rock Dumping	0.3	0.3	1.4
Waste Rock Stockpile Wind Erosion	0.9	0.9	1.4
Ore Removal	0.1	0.1	0.1
Ore Haulroad			
Fugitive Dust	737	110.6	91.7
Tailpipe Emissions			
NO_x	N/A	806.7	1,033.0
HC	N/A	12.6	16.0
CO	N/A	115.2	147.0
PM	N/A	26.4	34.0
Primary Crushing of Ore	N/A	0.7	2.9
Petroleum Storage			
Diesel Fuel			
Breathing Losses	N/A	Neg.	Neg.
Working Losses	N/A	Neg.	Neg.
Unleaded Fuel			
Breathing Losses	N/A	Neg.	Neg.
Working Losses	N/A	Neg.	0.3

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TABLE II-10 (Continued)

AIRBORNE EMISSIONS

Operations	Uncontrolled (lbs/hr)	Maximum 24-hr (lbs/hr)	Annual Average (tons/yr)
Residence/Dining Buildings			
PM	N/A	0.1	0.2
SO_2	N/A	0.2	0.9
CO	N/A	0.1	0.6
HC	N/A	Neg.	0.1
NO_x	N/A	0.6	2.8
Crusher/Mine Service Building			
PM	N/A	0.1	0.6
SO_2	N/A	0.5	2.2
CO	N/A	0.4	1.6
HC	N/A	0.1	0.3
NO_x	N/A	1.6	6.9
Mine Access Road			
Fugitive Dust	N/A	4.51	3.74
Tailpipe Emissions			
CO	N/A	0.66	2.88
NO_x	N/A	0.09	0.41
PM	N/A	0.02	0.07
VOC	N/A	0.07	0.29
Wilson Area Wharf			
Power Plant Fuel Storage			
Breathing Losses	N/A	Neg.	0.2
Working Losses	N/A	0.1	0.3
Diesel Fuel Storage			
Breathing Losses	N/A	Neg.	0.1
Working Losses	N/A	Neg.	0.1
Unleaded Fuel			
Breathing Losses	N/A	Neg.	Neg.
Working Losses	N/A	0.1	0.3
Planes and Helicopters			
SO_2	N/A	0.1	0.02
PM	N/A	-	-
CO	N/A	0.6	2.7
HC	N/A	0.1	0.3
NO_x	N/A	0.1	0.1

TABLE II-10 (Continued)

AIRBORNE EMISSIONS

Operations	Uncontrolled (lbs/hr)	Maximum 24-hr (lbs/hr)	Annual Average (tons/yr)
Tugboats (20 trips/yr)			
SO_2	N/A	0.4	0.1
PM	N/A	0.8	0.2
CO	N/A	0.4	0.1
HC	N/A	0.4	0.1
NO_x	N/A	2.1	0.5
35,000 DWT Tanker (10 trips/yr)			
SO_2	N/A	68	1.2
PM	N/A	16	0.3
CO	N/A	0.5	0.1
HC	N/A	2.5	0.1
NO_x	N/A	42	0.6

required. It is expected that 100 lbs of chlorine would be used every 2 weeks. Chlorination schedules would vary with bacterial slime populations. The cooling water would be discharged to the concentrator system for use in the ore grinding mills, thus minimizing the raw water demand and the liquid wastes. When the plant is expanded to a nominal 80,000 tpd, a cooling water system with a mechanical draft cooling tower may be installed. If a cooling tower is utilized, blowdown would be discharged into the tailings following appropriate dechlorination.

The liquid wastes such as the water softener spent reagent (NaCl solution), steam generator blowdown, and general washdown would be acceptable for reuse in the process. These wastes would be pumped to the 12,000 gallon waste holding tank. In addition, oily wastes, such as rejects from the fuel oil and lube oil centrifuges, would also be transferred to the waste holding tank. The oily wastes would be skimmed and drained into drums for disposal at the central incinerator and remaining wastewater would be checked daily to determine its quality and, if satisfactory, it would be pumped to the concentrator area for use in the process. However, if its quality is found to be unsatisfactory for the process, it would be treated prior to pumping to the concentrator area.

A separate 12,000 gallon tank would be used for wastewater not acceptable to the process. The wastewater will be generated when the gas turbines are washed (approximately once per month), and will contain Na, K, V, Pb, and other metals. The wastewater from this tank will be bled by gravity to the tailings thickener system at a very low rate. All site runoff will drain into the process area retention pond.

About 90 gpm of water would be used in the gas turbines for control of NO_x and would be lost by evaporation. If oils with high sulfur content are used, such as No. 6 fuel oil or crude oil, about 160 gpm of water (230,000 gpd) would be used for limestone slurry scrubbing of the turbine exhaust gases for SO_2 removal. Limestone from a quarry in Alaska, British Columbia, or the State of Washington would be used as the principal reagent in the scrubbers of the power plant. Twenty-five tons/day would be required. Most of the water used in scrubbing would be lost by evaporation, leaving behind the dissolved salts.

If used, the scrubber operation would produce liquid effluent containing calcium sulfate, calcium carbonate, and calcium bisulfite, trace metals, and some impurities originating from the limestone used in the scrubber. This effluent would be discharged as a continuous flow into the grinding circuit of the concentrator process.

From the switchgear of the power plant, electric power would be distributed by cables and overhead lines to the other plant facilities. Power to the mine site would be transmitted by cables routed through the conveyor tunnel. The overhead transmission line to

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the Wilson Arm wharf would follow the access road. The crusher would be powered through a 13.8 kV CLX type cable system strung through the coarse ore conveyor tunnel. Power for the supplemental water supply facilities would be provided by overhead transmission lines which generally follow the pipeline corridor. All overhead transmission lines will be designed to prevent electrocution of eagles.

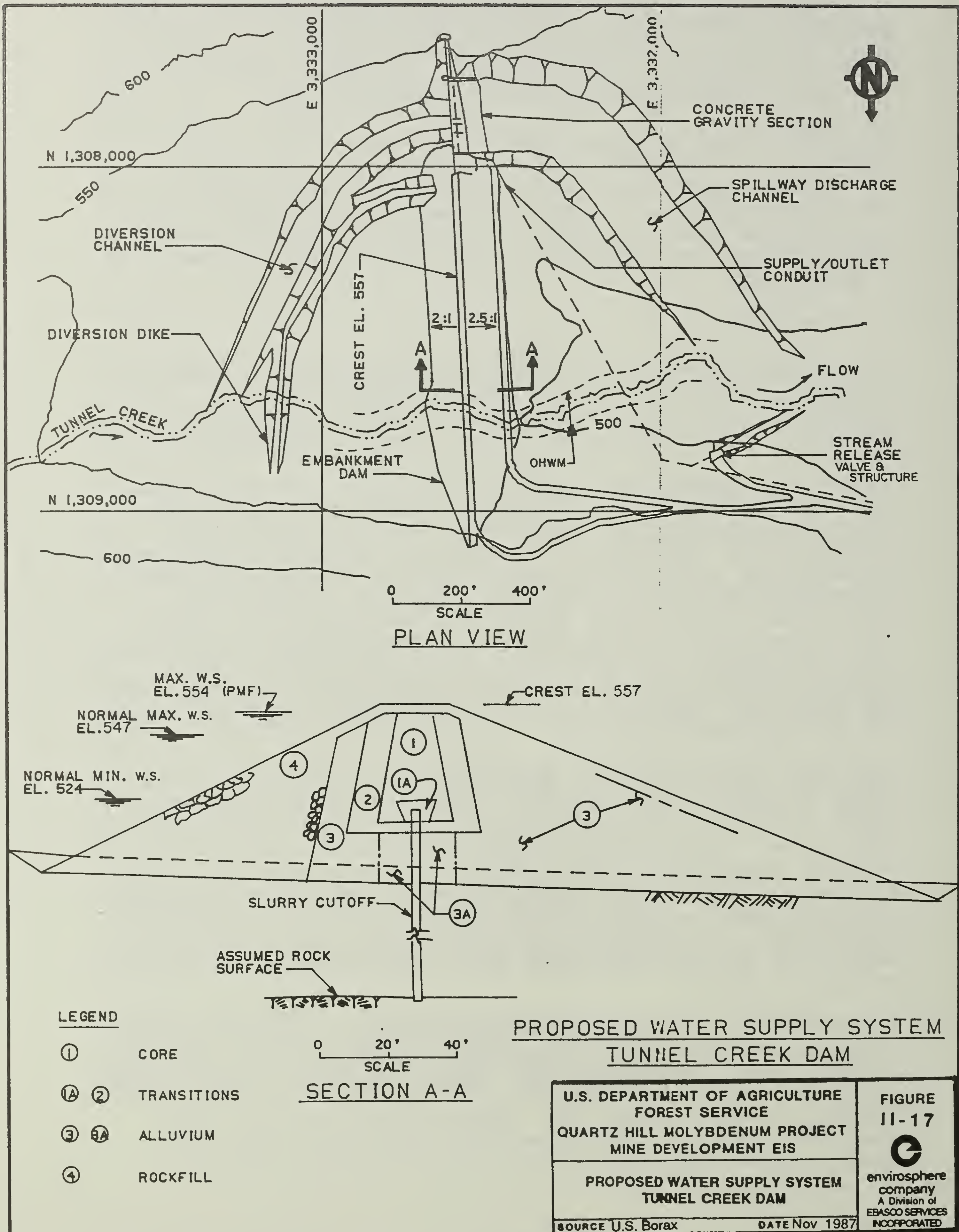
The use of the ore conveyor as the motive power for electricity generation is an additional source of electricity. The conveyor brings ore downward from the mine to the concentration facility. Because the ore is being moved from a higher to a lower elevation, braking action is required to control the speed of the conveyor. Mechanical energy can be captured from this braking action and converted into about 1 MW of electricity.

4. Water Supply

Water supply sources would be required at project facility locations for process, utility, fire protection, and potable water uses. Estimates of water supply requirements include an allowance for fire protection. A sufficient supply of water would be maintained in storage tanks to satisfy fire suppression requirements. Tunnel Creek, supplemented by water from intake facilities on the Blossom River, would be the primary supply of process and potable water under the proposed development plan. For the mill site, at a nominal ore production rate of 80,000 tpd, approximately 16,000 gpm of water would be pumped from a reservoir on Tunnel Creek just upstream from the concentrator when flow is sufficient. When flow in Tunnel Creek is insufficient to meet project demands and instream flow requirements, the Blossom River facilities would be utilized. Minimum streamflows would be maintained in Tunnel Creek. On an average annual basis, approximately 80 percent of the required water supply would come from the Tunnel Creek water supply reservoir with about 20 percent from the Blossom River facilities.

The Tunnel Creek dam would be approximately 52 ft high with a crest length of 1,500 ft (Figure II-17). It would be a zoned earth and rockfill structure with a concrete-lined open-channel spillway near the left abutment. Approximately 76,000 and 254,000 cu yd of rockfill and alluvium, respectively, would be required with approximately 6,000 cu yd placed below the ordinary high water mark (OHWM). The outlet works would be a conduit sized for stream releases as well as plant demands. The reservoir capacity would be 530 acre ft with an area of 35 acres. Runoff from the plant areas would be collected for use as makeup water in the mill process.

A supplemental water supply system would include an infiltration bed intake on the Blossom River and a 19,000 ft pipeline to the day tank (Figure II-18). The pipeline and pumping plant would be constructed to convey the water to the plant site. The pipeline and access road would connect to the mine access road. Water supplies for other project components, including the mine, would be obtained from local water wells or surface water diversions which are discussed with the



E 3,333,000
E 3,332,000
600
550
500
N 1,308,000
N 1,309,000
CONCRETE GRAVITY SECTION
SPILLWAY DISCHARGE CHANNEL
DIVERSION CHANNEL
SUPPLY/OUTLET CONDUIT
CREST EL. 557
2:1
2.5:1
A
A
DIVERSION DIKE
FLOW
TUNNEL CREEK
STREAM RELEASE VALVE & STRUCTURE
EMBANKMENT DAM
OHWM
0 200' 400'
SCALE
PLAN VIEW
MAX. W.S. EL.554 (PMF)
CREST EL. 557
NORMAL MAX. W.S. EL.547
NORMAL MIN. W.S. EL. 524
1
1A
2
3
4
3
SLURRY CUTOFF
3A
ASSUMED ROCK SURFACE
0 20' 40'
SCALE
SECTION A-A
LEGEND
1 CORE
1A 2 TRANSITIONS
3 3A ALLUVIUM
4 ROCKFILL
PROPOSED WATER SUPPLY SYSTEM
TUNNEL CREEK DAM
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
PROPOSED WATER SUPPLY SYSTEM
TUNNEL CREEK DAM
SOURCE U.S. Borax
DATE Nov 1987
FIGURE II-17
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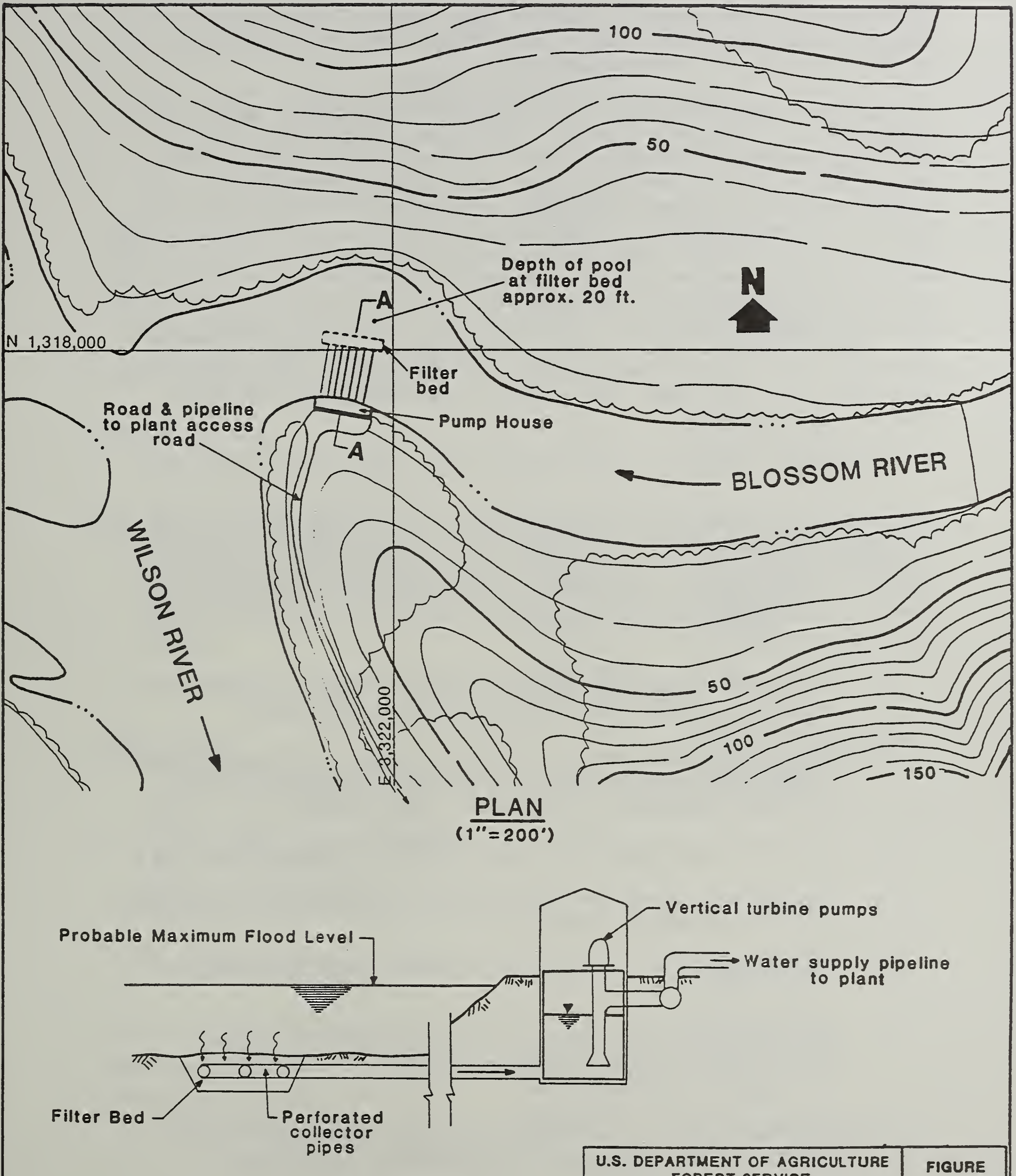

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

BLOSSOM RIVER WATER INTAKE & PUMPING STATION

SOURCE U.S. Borax DATE Nov 1987

FIGURE II-18

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description of the project component they serve. Table II-11 summarizes project water supply requirements and identifies the probable sources for these supplies.

In addition, three minor diversion dams would be used to supply water to the Wilson Arm marine terminal facilities and the mine service facilities as shown in Figure II-1. The installation of all three diversions would be essentially the same except for magnitude. A trench would be excavated across the stream and clean shot rock fill would be placed to serve as the foundation for an overflow weir. The water would be removed from the impoundment through a pipeline to the point of use. The water supply diversion for the marine facility would require the placement of approximately 25 cu yd of clean shot rock fill below the OHWM. The area of impoundment would be approximately 0.1 ac. Each of the two water supply diversions for the mine service facility would require the placement of approximately 45 cu yd of clean shot rock below the OHWM. The area of each impoundment would be approximately 0.2 ac.

5. Wastewater and Spill Control Facilities

The treatment and disposal of wastewater streams have been discussed in the description of each project component. Facilities for drainage and wastewater treatment would include sedimentation ponds, retention ponds, oil extractors, and sewage treatment plants or sanitary drain fields. In summary, project wastewater would be controlled by the following procedures:

- Establishing on site domestic waste treatment systems, site retention ponds, and industrial waste pretreatment
- Recycling to the extent possible process waste streams such as power plant cooling water, molybdenite concentrate and tailings thickener overflow, and site drainage
- Constructing impermeable and properly drained marshalling yards
- Diking and lining fuel storage sites to contain tank contents plus displacement volume
- Providing a Spill Prevention, Control, and Countermeasure (SPCC) Plan
- Providing drainage, sumps, and recycle within reagent buildings, mill and flotation facilities to prohibit spillage of reagent to watercourses
- Valving pipelines at stream crossings and provide leak detection instrumentation, and periodic inspections

TABLE II-11

QUARTZ HILL PROJECT
WATER SUPPLY REQUIREMENTS AND SOURCES

Facility	Amount Required (gpm)	Source
Mine Maintenance, ancillary buildings (wash bay, potable, fire protection), campsite	97	Diversion of local drainage
Primary Crusher Dust suppression, fire protection, mine roads	69	Diversion of local drainage
Processing Facilities Wet grind process water Flotation, concentration Utility: seals, wash down, spray Potable	12,820-16,000 (assumes 50 and 45 percent solids in tailings, respectively)	Tunnel Creek Reservoir and Blossom River facilities (re-use from power plant)
Power Plant Steam condenser cooling Process: oil wash, boiler makeup, NO_x control, gas turbine wash, gas scrubbing, floor and equipment wash (mostly discharged to processing facilities)	14,500	Tunnel Creek Reservoir and Blossom River facilities
Tunnel Creek Housing Facility	60	Tunnel Creek or tributary
Wilson Arm Marine Terminal	9	Diversion of local drainage
Construction Period Potable and Service	Unknown	Various sources (diversion and wells)

Source: Sheflott 1983a and Reim 1983 with modifications by U.S. Borax 1983b.

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Table II-12 lists each facility, its location, size, discharge amount, and discharge location. Figure II-11 presents a water use flowchart for the mine and process facilities showing rates, sources, uses, and discharges. No foundation dewatering is expected to be required during construction of facilities.

6. Solid Waste Disposal

The disposal of solid wastes has been discussed in the description of each major project component where solid wastes would be generated. Mill tailings and waste rock disposal have been described in detail and would not be discussed further here. The sludge from the flue gas desulfurization process (if used) of the power plant would be discharged to the tailings. Sediment from other settling ponds would be hauled to specifically designated areas in the waste rock disposal area.

The primary means of disposal of burnable solid waste (garbage, trash, oil rags, containers, etc.) would be by incineration. An incinerator capable of burning up to 2,800 tons per year of such material would be located near the Tunnel Creek plant. Solid wastes from other facilities would be trucked to the incinerator. Up to 65 tons per year of sewage sludge may also be fed into the incinerator or deposited with the waste rock in specially designated areas. The incinerator ash would also be taken to the waste rock disposal area. Ash would be containerized if necessary.

Large, bulky, salvageable solids, such as broken machinery parts, would be stored on site and periodically removed for sale as scrap or for disposal outside the Quartz Hill project area.

7. Other Ancillary Facilities

Communication and Navigation Facilities

Telephone, television, and radio communications facilities are anticipated for the project. Navigation aids include radar, radio, beacons, and buoys. Surface installations required to support the facilities include microwave towers, satellite antennae, relay stations, radar antennae, beacons, and buoys. Individual installations require relatively little space (on the order of a few hundred square ft), but they are often constrained to prominent locations in the topography. Detailed planning of design, siting, and timing of these facilities has not been completed.

Helicopter Landing Pads

Although land and water transportation would be the primary modes of travel, helipads would be installed near all project activity centers and in key locations for safety and maintenance emergencies. The area required for each helipad is less than 5,000 sq ft. Helipads would range in complexity from cleared areas to concrete slabs.

TABLE II-12

WASTEWATER TREATMENT FACILITIES

Facility	Location	Size/Volume	Discharge Rate	Discharge Location
Sedimentation Ponds:				
Interim Waste Rock Disposal and Mine Drainage	White Creek	1470 acre ft	-	White Creek
Interim Waste Rock Disposal and Mine Drainage	Beaver Creek	1000 acre ft	-	Beaver Creek
Waste Rock Disposal	Hill Creek	6800 acre ft	32 cfs (ave.)	Hill Creek
Waste Rock Disposal, Site Runoff, and Construction Tunnel Drainage	Beaver Creek	1300 acre ft	15 cfs (ave.)	Beaver Creek
Tunnel Drainage during Construction	Tunnel Creek tunnel portals	-	-	Tunnel Creek
Support Facility Runoff	Mine Site	-	32 gpm	Beaver Creek
Support Facility Runoff	Processing Plant	-	none	Used in Processing
Oil Extractors:				
Support Facility Sump	Mine Site	-	27 gpm	Sedimentation Pond
Support Facility Sump	Processing Plant & Power Plant	-	none	Used in Processing
Support Facility	Wharf	-	4 gpm	
Sewage Treatment Plants:				
Mine Facilities & Camp	Mine Services Area	-	32 gpm	Sedimentation Pond
Processing Plant & Camp	Processing Plant area	-	85 gpm	Wilson Arm
Wilson Arm Wharf	Wharf	-	7 gpm	Wilson Arm
Wilson Floating Camp	Wharf	-	-	Wilson Arm

Source: Reim 1983.

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Concrete Batch Plants

Several on-site batch plants would supply the estimated 80,000 cubic yards of concrete for construction of major project facilities. A concrete plant, including aggregate crushing equipment with a capacity of 100 cubic yards per hour, would be required for construction of the mine site facilities. It would be located near the crusher and would occupy 10 acres, including space for aggregate piles, cement storage bins, mixing and loading facilities, and equipment access. Makeup water would be drawn from Beaver Creek at 30,000 gpd. Site runoff and wastewaters would be collected in a water quality control pond and then released to Beaver Creek in compliance with NPDES effluent criteria. The batch plant would be set up at the start of construction and would be removed on completion of construction. After the concrete plant is removed, the site would be used for the plant yard area.

Construction of the molybdenum processing plant and associated facilities would require a second concrete plant, including aggregate crushing equipment with a capacity of 120 cubic yards per hour. The plant would be located at the construction site and would occupy 10 acres. Water would be drawn from Tunnel Creek at a rate of 30,000 gpd. Site runoff and wastewater would be collected in a sedimentation pond at the plant site, would be treated to meet NPDES criteria and would then be discharged to Tunnel Creek. The concrete plant would be set up at the start of construction and retained for the life of the operation. Plant size may be reduced after construction is completed.

Sand and Gravel Aggregate Extraction

Operation of the concrete batch plants and road surfacing would require large amounts of sand and gravel. The source of coarse aggregate on site would be the rock excavated at plant and road sites, supplemented when necessary by adjacent quarries. Fine aggregates would be removed from alluvial deposits on Beaver and Tunnel creeks where possible. The total approximate tonnage of sand and gravel aggregate required is estimated to be 600,000 tons. After extraction is completed, the area would be reclaimed by rounding off the contours and reseeding.

III. OTHER ALTERNATIVE PROJECT CONCEPTS

This chapter presents several project concepts which are reasonable alternatives to the applicant's proposed project. Each of these project "concepts" consists of several project "components" including the mine site facilities, the primary crusher, the ore transport, the mill, the tailings disposal system, and the housing needed to develop a complete project. Major components of the proposed project and each of the reasonable alternative project concepts that would be studied in detail in this EIS are presented in Table III-1. To understand an overall project concept, the reader should review the description of each individual component listed for that concept. The alternative project component descriptions are included in this section, where they are grouped by component type (Mine Site Facility Alternatives, Primary Crusher Alternatives, etc.). In cases where a project component is identical to that in the applicant's proposed project, the reader should refer to the previous chapter for a complete description of that component. The descriptions of the potentially feasible project components provided in this section describe each portion of the project concept alternatives to a level of detail allowing comparison with the applicant's proposed project. Figures III-1 through III-6 show the locations of all major project components for each of the alternative project concepts.

In several cases certain project components are incompatible with other project components and, therefore, cannot be combined to produce a reasonable project concept. For instance, since the on-land tailings disposal component involves a tailings impoundment in Tunnel Creek which would inundate the area needed for the Tunnel Creek mill site component, there is no reasonable project concept which incorporates the Tunnel Creek mill site with on-land tailings disposal. Alternative components incorporated into one or more project concepts for detailed study in the EIS are described fully. Several other alternative components have been considered, but have been eliminated from detailed study because of major engineering problems in implementing the alternative, excessive economic costs and/or severe environmental impacts that cannot be adequately mitigated. For each of these alternatives eliminated from detailed study, a brief description of the component is provided, along with an explanation of the engineering, economic, and/or environmental rationale for its elimination.

A. NO ACTION ALTERNATIVE

The no action alternative would result in no further development of the molybdenum deposit at Quartz Hill. Thus, none of the proposed facilities would be constructed. However, since U.S. Borax has patented mining claims, they would retain certain rights. The patented claims are now the private property (both surface and mineral) of U.S. Borax and would not revert to Forest Service ownership. Furthermore, Section 1110(b) of the Alaska National Interest Lands Conservation Act (ANILCA) stipulates that adequate and feasible access must be provided to inholders. Thus, in the no action alternative U.S. Borax would be permitted to leave the bulk sampling access road and wharf in place.

QUARTZ HILL PROJECT ALTERNATIVE CONCEPTS

Concept Title (Figure Snowing Concept Features)	Crusher and Ore Transport	Mill	Tailings Transport	Tailings Disposal	Townsite	Power Supply
Proposed Project						
Tunnel Creek Mill with Wilson Arm Tailings Disposal (Figure II-1)	Crusher at northwest edge of pit and conveyor in tunnel	Tunnel Creek site with one of several alternative water supplies (Tunnel Creek Reservoir and Wilson River well field)	Pipeline along access road to wharf on Wilson Arm, then submerged pipeline to submerged discharge point	Wilson Arm/Smeaton Bay	Commute or Bakewell or Wilson I or IIa or Phase-In	Power plant at mill
Other Alternatives						
Tunnel Creek Mill with Boca de Quadra Tailings Disposal and Commute Option (Figure III-1)	Crusher at northwest edge of pit and conveyor in tunnel	Tunnel Creek site with one of several alternative water supplies	From tailings thickener by launder and/or pipeline in tunnel to submerged discharge point	Inner basin of Boca de Quadra, with possible later extension to middle basin of Boca de Quadra or middle basin only	Commute	Power plant at mill
Tunnel Creek Mill with Boca de Quadra Tailings Disposal and Townsites (Figure III-1)	Crusher at northwest edge of pit and conveyor in tunnel	Tunnel Creek site with one of several alternative water supplies	From tailings thickener by launder and/or pipeline in tunnel to submerged discharge point	Inner basin of Boca de Quadra, with possible later extension to middle basin of Boca de Quadra or middle basin only	Commute or Bakewell or Wilson I or IIa or Phase-In	Power plant at mill
Beaver Creek Mill with Boca de Quadra Tailings Disposal (Figure III-2)	Crusher at northwest edge of pit and covered conveyor	Beaver Creek site with one of several water supplies	Tunnel and surface pipeline to submerged discharge point	Inner basin of Boca de Quadra with possible later extension to middle basin of Boca de Quadra or middle basin only	Commute or Bakewell or Wilson I or IIa or Phase-In	Power plant at mill or in Tunnel Creek
Beaver Creek Mill with Wilson Arm Tailings Disposal (Figure III-3)	Crusher at northwest edge of pit and covered conveyor	Beaver Creek site with one of several alternative water supplies	Pipeline along access road to wharf on Wilson Arm, then submerged pipeline to submerged discharge point	Wilson Arm/Smeaton Bay	Commute or Bakewell or Wilson I or II or Phase-In	Power plant at mill or in Tunnel Creek

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TABLE III-1 (Continued)

Concept Title (Figure Showing Concept Features)	Crusher and Ore Transport	Mill	Tailings Transport	Tailings Disposal	Townsite	Power Supply
Beaver Creek Mill with On-Land Tailings Disposal (Figure III-4)	Crusher at northwest edge of pit and covered conveyor	Beaver Creek site with one of several water supply alternatives	Pipeline along access road to Tunnel Creek and road to crest of tailings dam. Pipeline along Hill Creek, along Keta River, with one river crossing and up Aronitz Creek	Tailings impounded in Tunnel Creek and Aronitz Creek	Commute or Bakewell or Wilson I or IIa or Phase-In	Power plant at mill
North Meadow Mill with Boca de Quadra Tailings Disposal ("Keta Alternative") (Figure III-5)	Crusher at northeast edge of pit and covered conveyor	North Meadow site mill with one of several water supply alternatives	Pipeline along Hill Creek, down Keta River to Boca de Quadra, then submerged to discharge point	Inner basin of Boca de Quadra with possible later extension to middle basin of Boca de Quadra or middle basin only	Commute or Keta or Phase-In	Power plant at mill
North Meadow Mill with On-Land Tailings Disposal (Figure III-6)	Crusher at northeast edge of pit and covered conveyor	North Meadow site mill with one of several water supply alternatives	Pipeline along access road to wharf then up Aronitz Creek to impoundment. Pipeline along Beaver Creek and reclaimed Blossom Access Road to Tunnel Creek	Tailings impoundments in Tunnel Creek and Aronitz Creek	Commute or Bakewell or Wilson I or IIa or Keta or Phase-In	Power plant at mill

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FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

LOCATION OF FACILITIES FOR TUNNEL CREEK MILL WITH BOCA DE QUADRA TAILINGS DISPOSAL ALTERNATIVE

SOURCE ENVIROSPHERE CO. DATE NOV 83

FIGURE III-1

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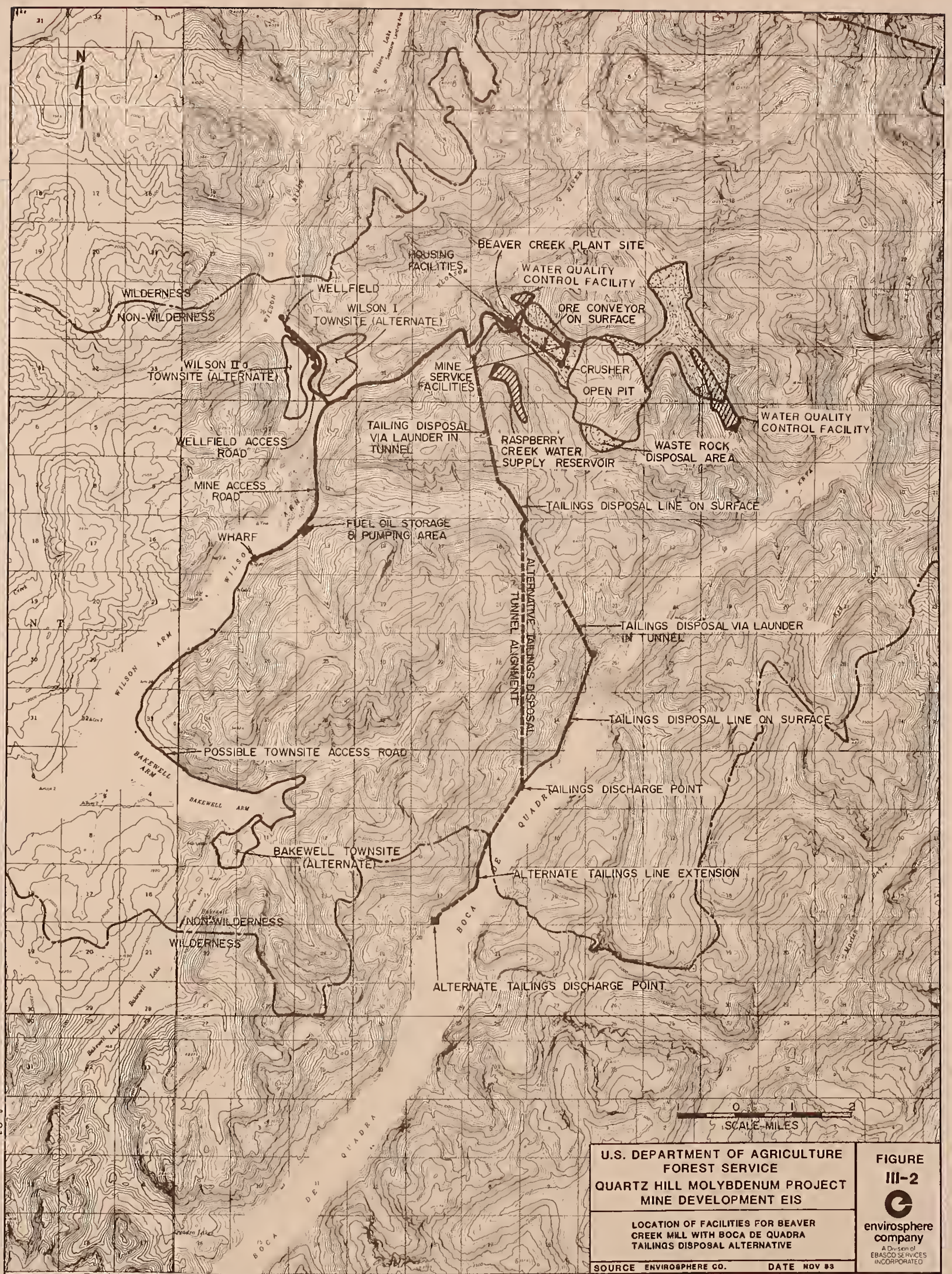

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

LOCATION OF FACILITIES FOR BEAVER CREEK MILL WITH BOCA DE QUADRA TAILINGS DISPOSAL ALTERNATIVE

SOURCE ENVIROSPHERE CO. DATE NOV 83

FIGURE III-2

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N
BEAVER CREEK PLANT SITE
WATER QUALITY CONTROL FACILITY
WELLFIELO
HOUSING FACILITIES
ORE CONVEYOR ON SURFACE
WILDERNESS
NON-WILDERNESS
WILSON I TOWNSITE (ALTERNATE)
WASTE ROCK OISPOSAL AREA
WILSON IId TOWNSITE (ALTERNATE)
CRUSHER
MINE SERVICE FACILITIES
OPEN PIT
WATER QUALITY CONTROL FACILITY
RASPBERRY CREEK WATER SUPPLY RESERVOIR
WELLFIELO ACCESS ROAO
WASTE ROCK OISPOSAL AREA
MINE ACCESS ROAO
TAILINGS OISPOSAL LINE
WHARF
FUEL OIL STORAGE AND PUMPING AREA
WILSON ARM
TAILINGS OISCHARGE POINT
POSSIBLE TOWNSITE ACCESS ROAO
BAKEWELL ARM
BAKEWELL TOWNSITE (ALTERNATE)
BOCA DE QUADRA
NON-WILDERNESS
WILDERNESS
NON-WILDERNESS
WILDERNESS
0 1 2
SCALE-MILES
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
LOCATION OF FACILITIES FOR BEAVER CREEK MILL WITH WILSON ARM TAILINGS DISPOSAL ALTERNATIVE
SOURCE ENVIROSPHERE CO.
DATE NOV 83
FIGURE
III-3
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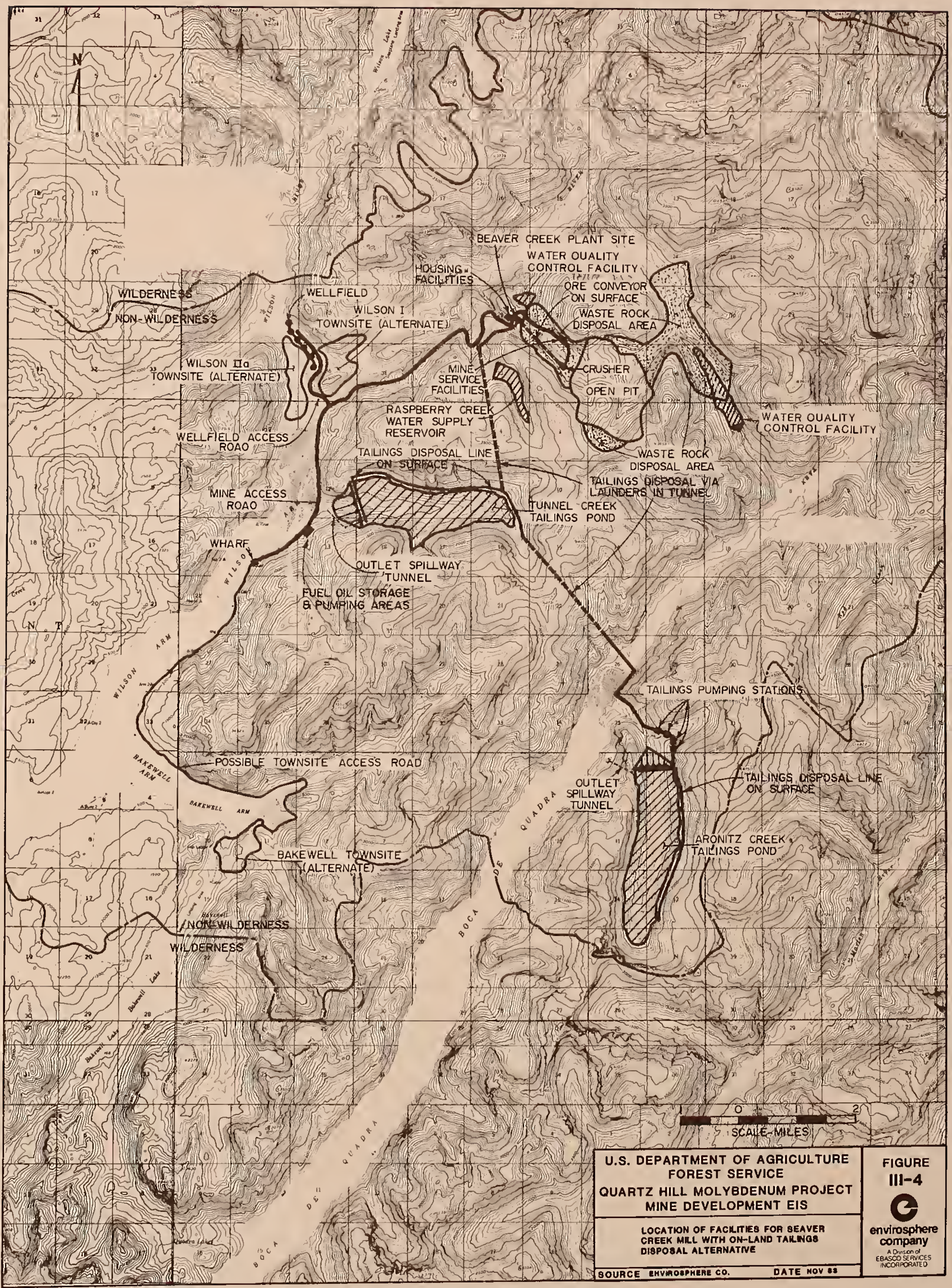
A Division of EBASCO SERVICES INCORPORATED


BEAVER CREEK PLANT SITE
WATER QUALITY CONTROL FACILITY
HOUSING FACILITIES
ORE CONVEYOR ON SURFACE
WASTE ROCK DISPOSAL AREA
WILDERNESS
NON-WILDERNESS
WELLFIELD
WILSON I TOWNSITE (ALTERNATE)
WILSON IIa TOWNSITE (ALTERNATE)
MINE SERVICE FACILITIES
CRUSHER
OPEN PIT
RASPBERRY CREEK WATER SUPPLY RESERVOIR
WATER QUALITY CONTROL FACILITY
WELLFIELD ACCESS ROAD
WASTE ROCK DISPOSAL AREA
TAILINGS DISPOSAL LINE ON SURFACE
TAILINGS DISPOSAL VIA LAUNDERS IN TUNNEL
MINE ACCESS ROAD
TUNNEL CREEK TAILINGS POND
WHARF
OUTLET SPILLWAY TUNNEL
FUEL OIL STORAGE & PUMPING AREAS
WILSON ARM
TAILINGS PUMPING STATIONS
POSSIBLE TOWNSITE ACCESS ROAD
TAILINGS DISPOSAL LINE ON SURFACE
OUTLET SPILLWAY TUNNEL
BAKEWELL ARM
BAKEWELL TOWNSITE (ALTERNATE)
ARONITZ CREEK TAILINGS POND
BOCA DE QUADRA
NON-WILDERNESS
WILDERNESS
0 1 2
SCALE-MILES
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
FIGURE III-4
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LOCATION OF FACILITIES FOR BEAVER CREEK MILL WITH ON-LAND TAILINGS DISPOSAL ALTERNATIVE
SOURCE ENVIROSPHERE CO.
DATE NOV 83

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QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

LOCATION OF FACILITIES FOR NORTH MEADOW MILL WITH BOCA DE QUADRA TAILINGS DISPOSAL ALTERNATIVE

SOURCE ENVIROSPHERE CO. DATE NOV 86

FIGURE III-5

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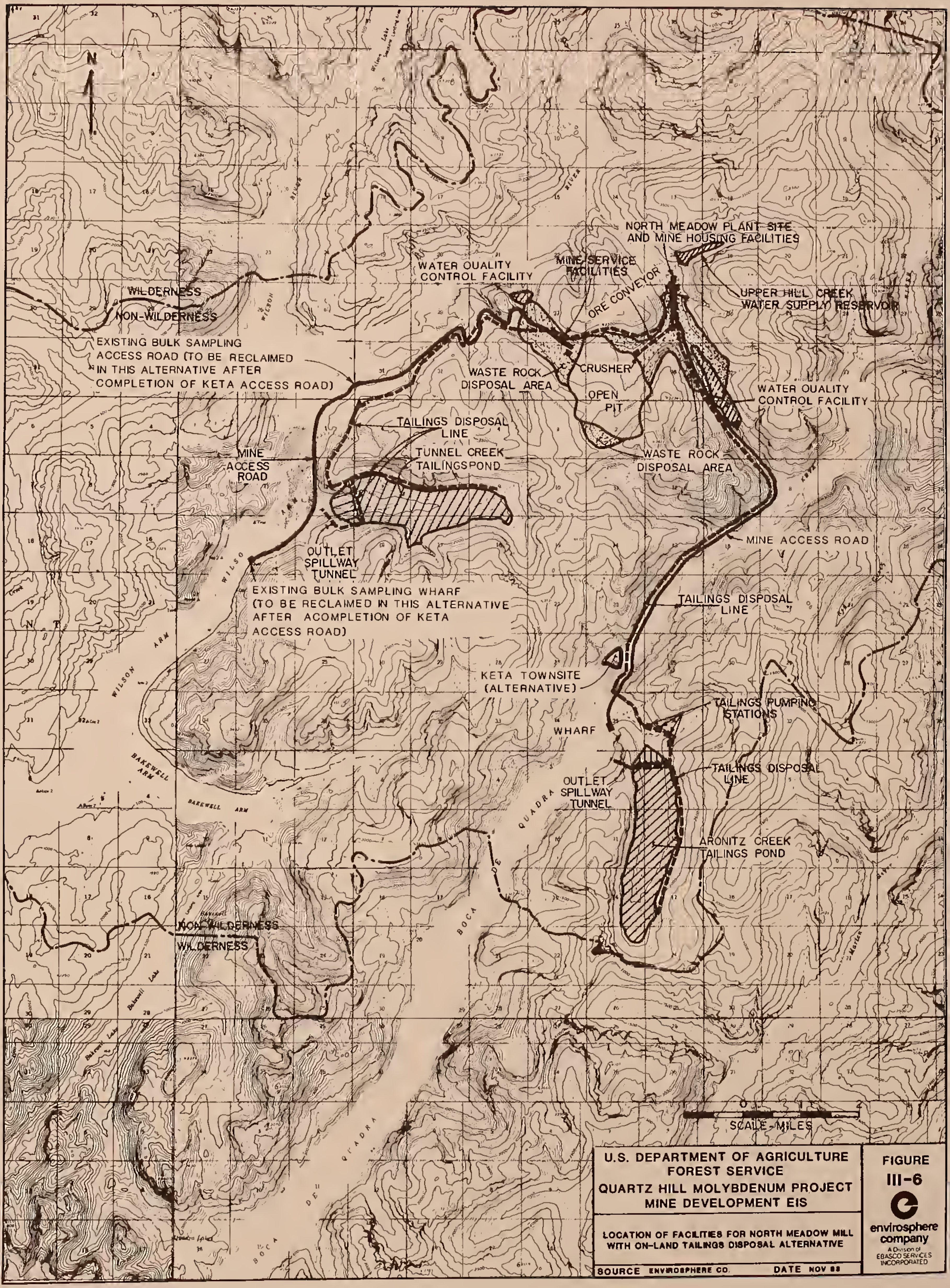
N
NORTH MEADOW PLANT SITE
AND MINE HOUSING FACILITIES
WATER QUALITY
CONTROL FACILITY
MINE SERVICE
FACILITIES
ORE CONVEYOR
UPPER HILL CREEK
WATER SUPPLY RESERVOIR
WILDERNESS
NON-WILDERNESS
EXISTING BULK SAMPLING
ACCESS ROAD (TO BE RECLAIMED
IN THIS ALTERNATIVE AFTER
COMPLETION OF KETA ACCESS ROAD)
WASTE ROCK
DISPOSAL AREA
CRUSHER
OPEN
PIT
WATER QUALITY
CONTROL FACILITY
TAILINGS DISPOSAL
LINE
TUNNEL CREEK
TAILINGSPOND
MINE
ACCESS
ROAD
WASTE ROCK
DISPOSAL AREA
MINE ACCESS ROAD
OUTLET
SPILLWAY
TUNNEL
EXISTING BULK SAMPLING WHARF
(TO BE RECLAIMED IN THIS ALTERNATIVE
AFTER ACOMPLETION OF KETA
ACCESS ROAD)
TAILINGS DISPOSAL
LINE
KETA TOWNSITE
(ALTERNATIVE)
TAILINGS PUMPING
STATIONS
WHARF
OUTLET
SPILLWAY
TUNNEL
TAILINGS DISPOSAL
LINE
WILSON ARM
BAKEWELL ARM
BOCA DE QUADRA
ARONITZ CREEK
TAILINGS POND
NON-WILDERNESS
WILDERNESS
SCALE-MILES
0 1 2
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
LOCATION OF FACILITIES FOR NORTH MEADOW MILL
WITH ON-LAND TAILINGS DISPOSAL ALTERNATIVE
SOURCE ENVIROSPHERE CO.
DATE NOV 88
FIGURE
III-6
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B. MINE SITE FACILITY ALTERNATIVES

The mine site is fixed by the location of the ore body, a large porphyry type mineral deposit located at and close to the surface. The feasible mining method is surface, or open pit, mining. The options directly associated with the mine site are: a) initial and final mining/milling rates; and b) sites for disposal of waste rock and overburden materials.

1. Mining/Milling Rates and Temporary Shutdown

The proposed development concept entails a production rate of a nominal 80,000 tons per day (tpd) of ore, with a startup phase at a nominal 40,000 tpd of ore for the first 4 to 6 years.

Alternative development plans involve other mining/milling rates and variations in the timing for achieving these production rates. For example, one option consists of a relatively constant mining/milling rate of 40,000 tpd of ore. A second option consists of incremented expansion to 80,000 tpd. Another option consists of an eventual expansion from 40,000 tpd to 80,000 tpds over an extended (10 to 15 year) period. From an engineering and logistics standpoint, these options are all considered viable.

Variations in mining/milling rates are likely to affect the following project aspects:

- Size and amount of activity of the equipment fleet in the mine site and mill site areas
- Requirements for utilities, including electric power, water supply, and waste treatment and disposal
- Duration of mining activity
- Size of the workforce
- Volume rate of tailings discharge
- Volume rate of emissions and effluent discharge
- Amount of vehicular, boat, and air traffic connected with site activities.

The selection of the optimum mining/milling rate would be dictated by the economics of mine development, and economic conditions of the molybdenum market. However, the variability of the milling rates would be constrained by the design of the processing facilities. At present two processing lines each of 40,000 tpd nominal capacity are planned. While each line could vary from this capacity by 10 to 15 percent due to the variability in the feed ore, downtime, etc., the workforce required to operate the lines would remain the same. Due to the operating characteristics of each line it is not feasible to vary the

production from each line by more than this 10 to 15 percent. If one line were shut down to reduce production, approximately 70 to 75 percent of the original workforce would still be required. This proportionally larger workforce and other factors would make it uneconomic to operate at the lower production rate of 40,000 tpd. Thus, no significant variability in workforce related to shifts in production levels was examined in this EIS, other than the shutdown scenario described below.

Based on recent experience with fluctuations in the molybdenum market and its effects on operating mines, after the project operations have begun, the Quartz Hill mine operations could be temporarily shut down due to market conditions. Although it is impossible to accurately predict the likelihood or timing of such a temporary shutdown, a scenario has been developed for the purpose of this EIS. At the time of the impending temporary shutdown, the mine and mill is assumed to be operating at its nominal 80,000 tpd capacity with a full complement of operating personnel. The first layoff would reduce the labor force to 300 who would be involved in preparing the mine and mill for the shutdown period. Within approximately one month a second layoff would reduce the workforce to a skeleton management, maintenance, and caretaker crew of approximately 175. During the period of the shutdown, maintenance would include pit dewatering, some avalanche control as needed, operation of the water quality control facilities, maintenance of the access roads, operation of auxiliary power supply, permit monitoring and environmental compliance work, and operation of the potable water supply, the sewage treatment plant and limited housing and services. The shutdown would probably last between 4 months and 2 to 3 years. For the purposes of this EIS, it is assumed to be approximately 15 to 18 months, based on the past experience of AMAX's Colorado molybdenum mines. As the project restarted production, the mine would begin with a capacity of 40,000 tpd with a workforce of about 625. Within 9 months of the restart, the mine and mill would be expected to increase production to a nominal 80,000 tpd and have a full workforce.

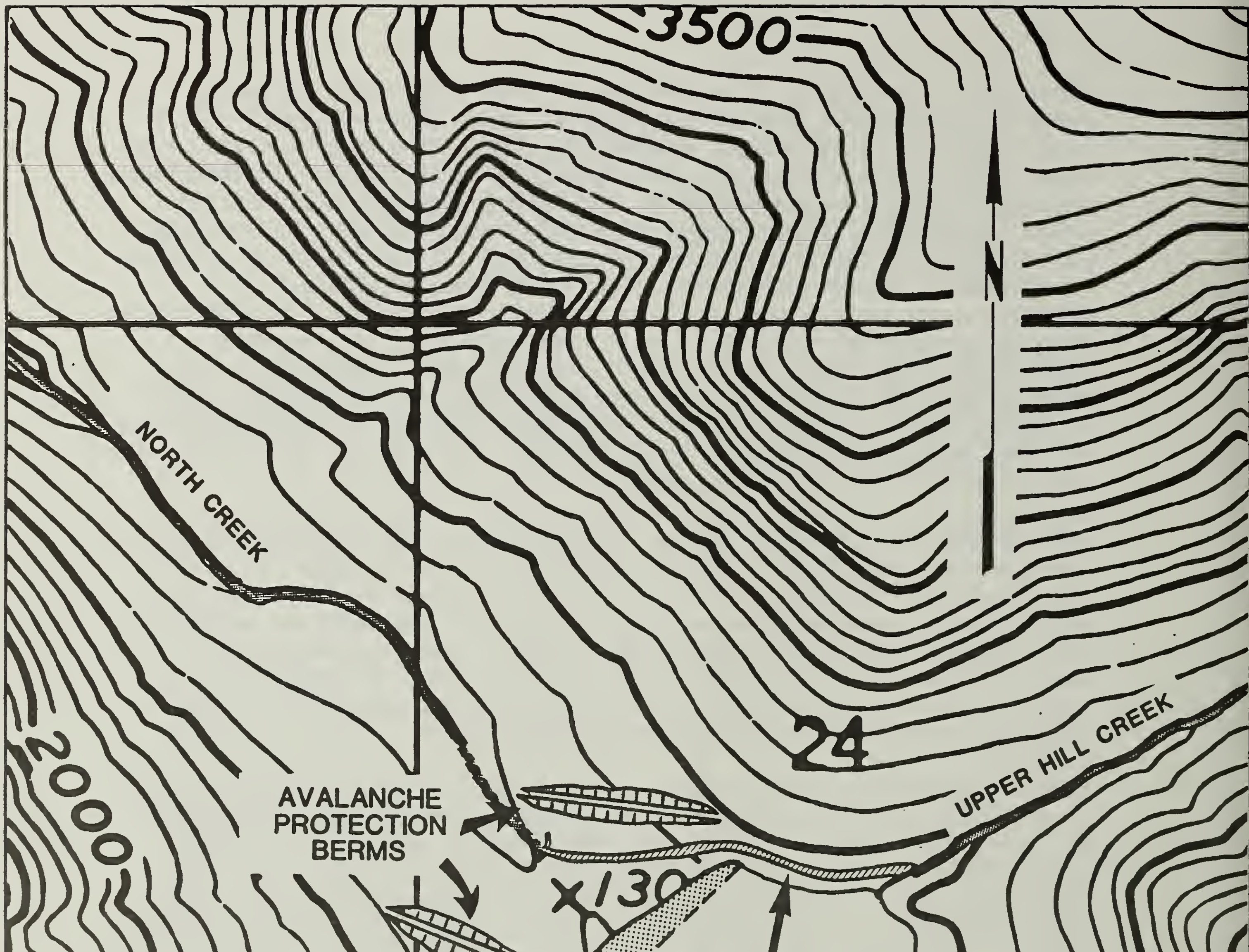
2. Waste Rock and Overburden Materials Disposal Sites

The proposed development concept involves waste rock disposal in the valleys of Beaver Creek, White Creek, and Hill Creek (see Figure II-1). Other alternative waste rock disposal sites studied include Raspberry and Smith creeks. The Raspberry Creek site would require a longer haul from the pit, would have a smaller capacity than other sites, and would be located at a higher elevation than the proposed waste rock dumps. The Smith Creek site would be close to the mine and have sufficient capacity to replace a portion of the proposed dumps, but would require an approximately 1,150 vertical ft greater climb for the haul trucks. Since haul distances and elevations differences significantly affect haulage costs, these sites were judged to not be feasible due to economic considerations. They would offer no environmental advantages and would not totally replace the proposed dump sites. No other feasible waste rock dump locations were

identified. Economics of hauling waste rock over large distances preclude use of more distant valleys for waste rock disposal. Disturbances associated with construction of sedimentation ponds, haul roads and maintenance associated with waste rock disposal at these more distant locations would result in additional environmental impacts. Since large quantities of waste rock and overburden must be disposed, alternatives to the proposed development concept for location of waste rock disposal areas are limited, involving minor variations in boundaries of these sites in close proximity to the pit. Disadvantages associated with this alternative include additional disturbance associated with extensions of waste disposal site boundaries. These modifications to the waste rock area would have no significant impact on other aspects of the proposed development concept. Maintenance and reclamation activities would be essentially the same as those described for the proposed development concept.

Construction of the North Meadow Plant (Figures III-5 and III-6) would require that boundaries of the waste rock pile be adjusted to provide for the land requirements of the plant facilities. Since the land requirement is minimal (approximately 160 acres for process and power plant facilities), some adjustments in waste rock disposal area boundaries would be required. Compensating waste rock disposal area would be obtained by adjusting the disposal area boundaries in the divide area separating Hill Creek and North Creek.

Rather than having the drainage from the portion of Hill Creek upstream of the waste rock area flow through the coarser rock at the bottom of the waste rock dumps as planned in the proposed project, the upper portion of Hill Creek could be diverted around the upper end of the waste rock area with the diversion channel contouring over the divide and discharging to the headwaters of North Creek. This channel would divert a drainage area of approximately 3.0 square miles and would have a rectangular cross-section with a width of 12 ft and a depth of 6 ft to handle the 100-year flood event. The channel would be lined and would be approximately 2,500 ft long as shown in Figure III-7. The steep channel gradient of approximately 8 percent would result in high flow velocities in the channel. Channel excavation and backfill are estimated to total 15,000 cu yd and 3,000 cu yd, respectively. Portions of the channel alignment would cross potential avalanche zones and would require avalanche protection. Avalanche berms, constructed of waste rock, would require approximately 620,000 cu yd of material. Permanent access to the channel alignment would be required to permit inspection and maintenance. This diversion channel would require frequent maintenance to minimize the possibility of blockage by avalanches or flood debris.


3500
N
NORTH CREEK
24
UPPER HILL CREEK
2000
AVALANCHE
PROTECTION
BERMS
130
UPPER HILL CREEK
DIVERSION CHANNEL
1450'
WASTE ROCK
DUMPS
0 500 1000 2000
SCALE - FEET
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
UPPER HILL CREEK
DIVERSION CHANNEL
SOURCE U.S. BORAX
DATE MAR 84
FIGURE
III-7
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The use of sidehill diversion channels upslope of the waste rock disposal areas which would intercept overland runoff and small streams before they enter the waste rock disposal areas has been investigated, but eliminated from detailed consideration due to problems related to the maintenance of such structures. Diversion ditches around the waste rock disposal area are not considered feasible, due to: (1) the condition of the forest floor - ditches would tend to clog with debris and flood during times of high runoff; (2) avalanche hazard - portions of the ditches would cross known, active avalanche paths and could be clogged or lost completely; and (3) potential for increasing landslides - ditches would tend to saturate downslope areas, destabilizing the soil and increasing landslide potential. Although the ditch could be covered to protect it from some of these hazards, inlets would still tend to clog with debris during runoff events.

C. PRIMARY CRUSHER ALTERNATIVES

The proposed crusher location would be on the northwest edge of the open pit. Alternatives are described in this section.

1. Northeast Pit Edge Crusher

An alternative location for the crusher is at the northeast edge of the mine area in the White Creek Drainage as shown in Figures III-5 and III-6. This site is practical only for a North Meadow location for the mill. This site would involve construction of the crusher on waste rock fill instead of on natural ground as at the proposed Bear Meadow site. Construction on the waste rock fill is expected to be more costly, however, the proposed facilities at this site and the operations would be similar to those proposed at the Bear Meadow site. Reclamation would also be similar to that described for the Bear Meadow site.

2. Crusher at the Mill Site

Other options have been considered which would involve locating the crusher away from the mine limits. These would involve transport of the mined ore sized at less than 4 ft to the mill site with crushing done at the mill. Because the size of the raw ore coming from the mining operation would make conveyors or tramways impractical, truck or rail transport would be required to carry the ore to the crusher. Truck transport would result in higher fuel usage and the need for a more extensive haul road network than would an on-mine-site crusher. Since there is no engineering, economic, or environmental incentive to locate the crusher away from the mine limits, this option was eliminated from detailed study.

D. ORE TRANSPORT ALTERNATIVES

A belt conveyor in a tunnel is the proposed means of ore transport. Several alternative ore transport modes have been evaluated.

1. Rail

One option for transporting the ore from the crusher to the mill is to use a rail system in a tunnel. It is anticipated that the cost of this system would be higher than that of a conveyor for both construction and operation. No significant engineering problems with this system are anticipated. However, since there are also no significant environmental advantages to a rail system and since the power generating capacity of the belt conveyor would be lost, this option has been eliminated from detailed consideration.

2. Tramway

A tramway system from the crusher to the mill was also considered. To reach the Tunnel Creek mill site the tramway would follow a route overland across a high ridge, approximately 1,000 ft above the crusher location. The alignment would be cleared and maintained. Maintenance of the facility could be difficult during adverse weather and snow conditions. Spillage of crushed ore could occur occasionally along the alignment. This alternative has been eliminated because of environmental considerations (additional disturbed acreages and reduced aesthetics) and because it offers no engineering or economic advantages.

3. Truck

Truck transportation of the crushed ore was eliminated based on a combination of economic and environmental considerations. The grade and distance involved to any of the potential mill sites would make truck transportation very expensive. The road system from the mine to mill would have to be improved to meet haul road criteria, resulting in additional disturbed area. The potential for worker injuries or death is greater for trucking than for the proposed conveyor.

4. Slurry

A slurry system transports a mixture of ground ore and water in a pipeline. It requires extensive crushing and grinding facilities at the mine site and a source of water for slurrying. Slurry transport of the crushed and ground ore to the mill was eliminated as a significant alternative based upon engineering and economic considerations.

5. Barge Transport to Off Site Mill

Transporting the ore to an off site mill via a barge was considered but eliminated because of the extremely high transportation costs involved. Transportation costs of raw ore would be approximately 600 to 700 times higher than the cost of transporting molybdenum concentrate.

6. Ore Transport Routes

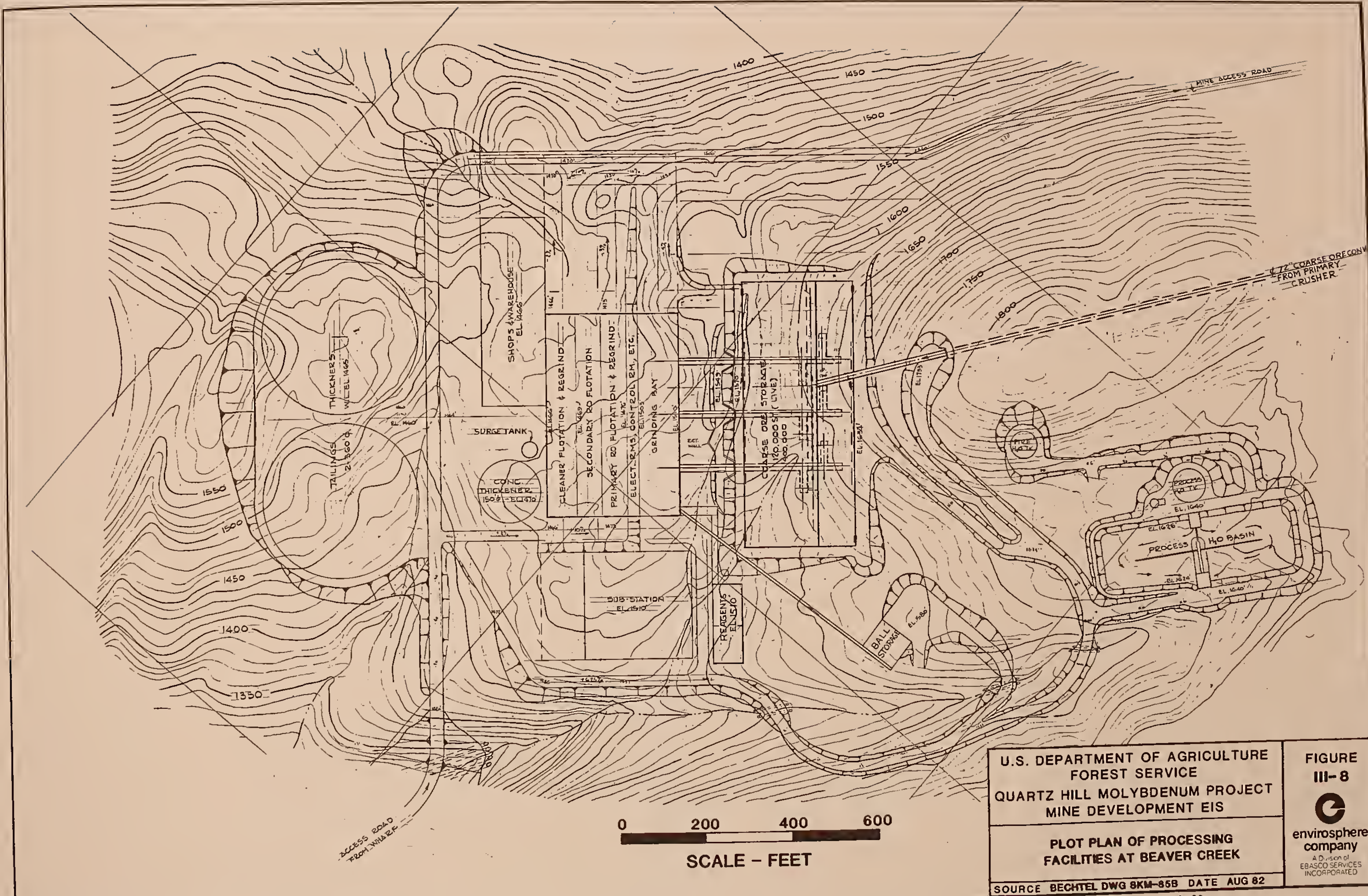
Alternative ore transport routes are needed for the alternative mill sites at Beaver Creek and North Meadow (these sites are described in detail in the following section of this Appendix). The crushed ore would be transported by a 60-in. wide, 8,500 ft conveyor belt along Beaver Creek to the Beaver Creek Mill Site as shown in Figures III-2 through III-4. The conveyor would be totally enclosed and have an interior service walkway. For the North Meadow Mill Site ore transport would be by conveyor belt along the edge of the waste rock disposal pile as shown in Figures III-5 and III-6. Reclamation at the end of mine life would include removal of equipment, recontouring and revegetation.

E. PROCESSING FACILITY ALTERNATIVES

The proposed development concept locates the mill and processing facilities, including coarse ore storage, grinding mills, flotation cells, concentrate dewatering, filtering, and shipping and ancillary facilities in the Tunnel Creek valley. Alternatives to the mill site location include a site in the Beaver Creek valley and a site location at North Meadow. The water needs and the emissions and effluents associated with the concentrator and support facilities are substantially the same, regardless of the mine development concept. Energy needs may vary, depending on transmission distances and on energy needs associated with water supply for the concentrator and the power plant. Sites more distant from the wharf would also result in higher fuel usage for truck transport of materials between the mill and wharf.

1. Beaver Creek Site

A conceptual plot plan for a mill site location at Beaver Creek is shown in Figure III-8. Since the facilities required for the milling process are substantially the same regardless of the mill site chosen, areas of surface disturbance are approximately equal (about 210 acres) for all of the alternatives considered. The Beaver Creek site would require more substantial structures than Tunnel Creek to handle the higher snow loads. Placement of the facilities within the mill site area may vary from one alternative to the next due to differences in the topographic setting between the sites. There are two variants associated with the Beaver Creek plant site alternative involving location of the power plant facilities. The first variant involves location of the power plant in Tunnel Creek, while the second variant involves placement of the power plant facilities at the mill site at Beaver Creek.



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QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

PLOT PLAN OF PROCESSING FACILITIES AT BEAVER CREEK

SOURCE BECHTEL DWG SKM-85B DATE AUG 82

FIGURE III-8

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The total road requirements associated with the Beaver Creek mill site (9 miles) would be less than those required at the Tunnel Creek mill site (11 miles). The variant with a power plant in Tunnel Creek would require construction of an access road within the valley of Tunnel Creek for access to the power plant (see Figure III-1) requiring an additional 2 miles of access road construction. With the alternative of land disposal of tailings in Tunnel Creek, there would not be sufficient room for the power plant to be located below the final toe of the rock filled tailings dam. Placement of the power plant at the mill site would not require additional access road construction beyond that necessary for access to the mill site.

Selection of the Beaver Creek plant site would be accompanied by reduced ore conveyor length aligned parallel with the Beaver Creek valley. The tailings disposal line to either Boca de Quadra or Wilson Arm would be substantially longer for the Beaver Creek plant site alternative. The alignments for the alternative tailings disposal lines to Boca de Quadra, Wilson Arm and on-land impoundments from the Beaver Creek plant site alternative are indicated on Figures III-2 through III-4. Water needs and the emissions and effluents associated with the concentrator and support facilities would not change regardless of the mill site location. However, while a power plant site at Tunnel Creek would rely on the Tunnel Creek reservoir as the primary water source, location of the power plant at the mill site at Beaver Creek would require development of an alternate water supply. It is likely that such an alternate supply could be developed from several sources, including a storage reservoir constructed on Raspberry Creek, an infiltration bed on the Blossom River, or a well field developed in the Wilson River floodplain, upstream of the confluence of the Blossom and Wilson rivers. These water supply sources are discussed in a later section on water supply alternatives.

The energy requirements for a Beaver Creek plant site are expected to be somewhat greater than the energy requirements of a Tunnel Creek plant site. This is due in large part to the increased energy needed to deliver water to the higher elevation at the Beaver Creek site (approximate elevation 1,500 ft above mean sea level) as compared to the Tunnel Creek site (approximate elevation 450 ft above mean sea level).

Commuting distances for the Beaver Creek plant site would be longer than those associated with a Tunnel Creek plant site.

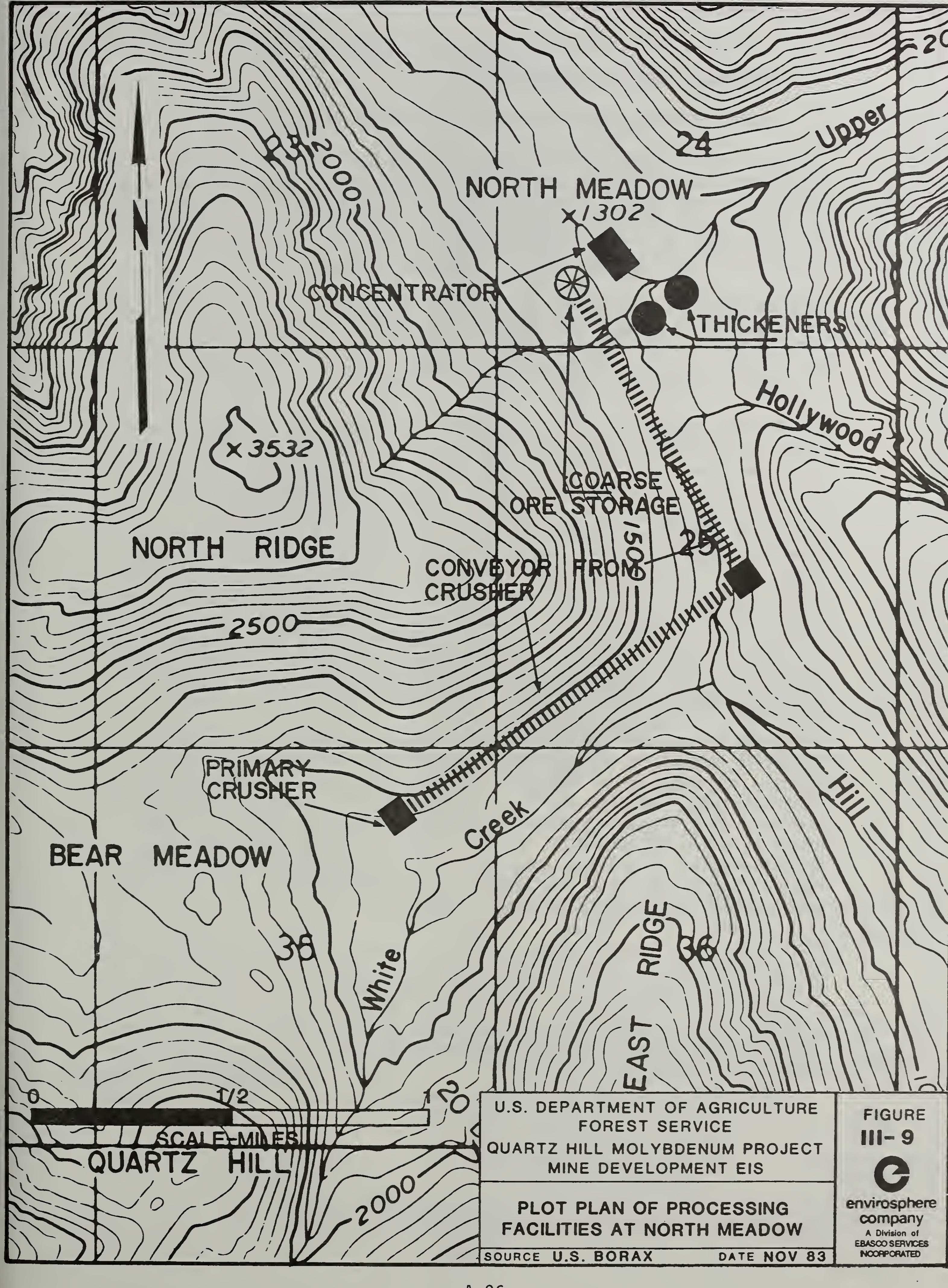
The Beaver Creek site would result in significantly increased truck traffic on the mine access road with attendant impacts on fuel usage, likelihood of accidents, etc. During construction of the mill, large modules, for the concentrator, would not be used due to the grades and curves on the mine access road. Prefabrications and preassemblies for the mill would be hauled up the road, although some further widening than planned in the proposed project might be necessary to accommodate

these assemblies. All mill steel work and truss work would also have to be hauled from the wharf. During the operations phase, reagents would be hauled up to the mill, while molybdenum concentrate would be hauled out to the wharf. An average of approximately 40 tons/day of grinding balls and 30 tons/day of liners for the ball mills would also have to be hauled from the wharf to the mill. In addition, supplies of fuel and commuting workers would travel this road on a regular basis.

Site maintenance, except for increased snow removal and other factors associated with colder temperatures and reclamation activities, would be about the same as those described for the proposed mill site location on Tunnel Creek. Construction costs and site maintenance costs during winter months would be much higher due to greater distance from the wharf and since mine and mill access road to the wharf would be crucial to operations.

2. North Meadow Site

The conceptual plot plan for a mill site location at North Meadow is shown in Figure III-9. Since the facilities required for the milling process are the same regardless of the mill site chosen, areas of surface disturbance connected with the mill site are approximately equal for all of the alternatives considered. As with the Beaver Creek site, placement of facilities within the mill site area may vary due to differences in the topographic setting between the sites. The elevation of the North Meadow site would result in much heavier snowfall than at Tunnel Creek and, thus, structures would have to be designed to handle the heavier snowloads, resulting in higher construction costs. Placement of the milling facilities at the North Meadow site would require construction of 3 miles of additional mine access roads in the area north of the pit boundary. In addition, some relocation of the proposed waste rock disposal area boundaries would be required to accommodate the mill site and power plant facilities. For the North Meadow mill site, it is likely that the primary crusher would be located on the northeastern perimeter of the pit, since this would be the preferred location from an engineering and environmental standpoint. The distance required for ore conveyance from the pit to the milling facilities would be substantially less than the distance associated with a mill site at Tunnel Creek. The length of the tailings disposal line would be increased by about 5 miles over that associated with the Tunnel Creek plant site. The alignments of the ore conveyor and the tailings disposal line for the North Meadow alternative are shown in Figures III-5 and III-6. Site maintenance and reclamation activities would be the same as those described for the proposed mill site location at Tunnel Creek, except for increased snow removal, other factors associated with colder temperatures, and energy requirements for pumping water from the supplemental supply. Construction costs and site maintenance costs during the winter months would be much higher due to the greater distance from the wharf and since the mine and mill access road to the wharf would be crucial to operations. The transportation of people and materials from a wharf would be similar to that described for the Beaver Creek mill site.



NORTH MEADOW
1302
CONCENTRATOR
THICKENERS
Upper
24
2000
Hollywood
3532
COARSE
ORE STORAGE
NORTH RIDGE
1500
25
CONVEYOR FROM
CRUSHER
2500
PRIMARY
CRUSHER
Creek
Hill
BEAR MEADOW
35
White
RIDGE
36
EAST
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MINE DEVELOPMENT EIS
PLOT PLAN OF PROCESSING
FACILITIES AT NORTH MEADOW
SOURCE U.S. BORAX
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FIGURE
III- 9
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F. TAILINGS DISPOSAL ALTERNATIVES

1. Inner Basin Boca de Quadra Marine Tailings Disposal

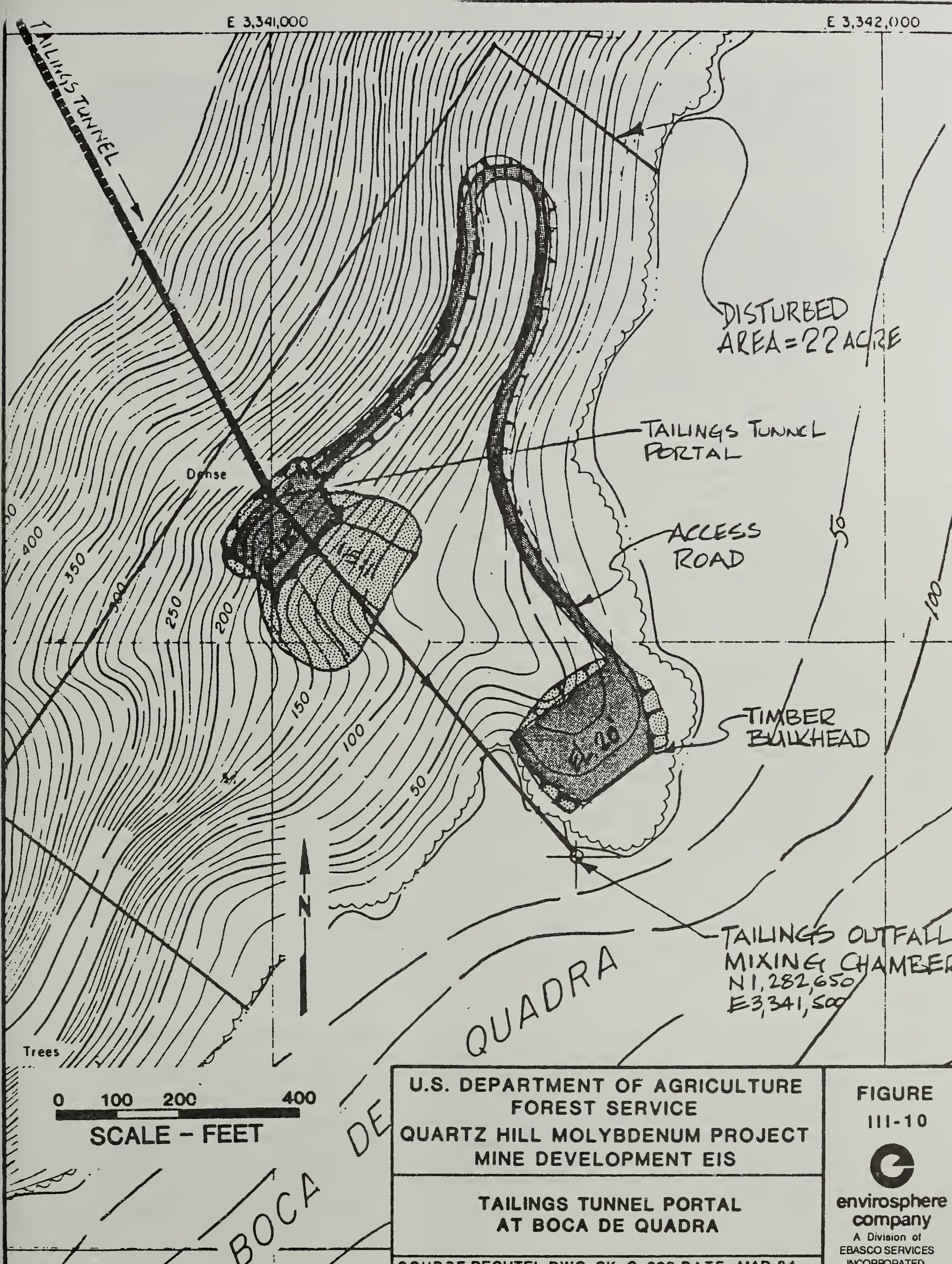
Tailings disposal would be by transport of the tailings from the thickeners at the Tunnel Creek mill site through a tunnel to the Boca de Quadra inner basin. The tunnel would have a length of approximately 28,000 ft, a width of 9 ft, and a height of 11 ft. The tailings would be discharged at a depth of approximately 150 ft. The proposed location of the tailings outfall is shown on Figure III-1.

Construction of the tunnel would create a surface disturbance of 4 ac in Tunnel Creek, and 25 ac at the Boca de Quadra portal area. Merchantable timber resources would be used in construction or sold to an outside contractor, while waste timber would be slashed and burned or placed in disposal areas.

During the construction of the tunnel, approximately 120,000 cu yd of waste rock would be removed. Waste rock from the Tunnel Creek end would be used in the construction of the Tunnel Creek water supply reservoir dam and other facilities. Excess waste rock would be deposited at a disposal site. This disposal site would have a perimeter ditch to intercept runoff from above the site. Storm runoff from the waste rock site would discharge into a sedimentation pond sized for a 10-year, 24-hour runoff event. Waste rock at the Boca de Quadra end would be used to construct a pad for construction facilities at the tunnel portal. Access roads to the tunnel portals would be required, and a small dock would be required at the Boca de Quadra end as shown in Figure III-10. Construction of a bulkhead at the Boca de Quadra end would involve placement of approximately 3,000 cu yd of rockfill material over 0.2 ac of area below the high tide level.

Construction equipment needs have not been determined because the tunneling method is not yet established. After construction of the tunnel, an open launder would be installed to carry the tailings. Alternatively, two high density polyethylene pipelines could be used; however, this is not proposed at the present time. Both pipelines would be required for an 80,000 tpd plant. A sedimentation basin would be constructed in the pad area at both the Tunnel Creek and Boca de Quadra portals to treat groundwater flow intercepted by the tunnel and construction area runoff to NPDES standards.

From the Boca de Quadra tunnel portal, tailings would be transported through two 32-in. diameter pipelines and a series of drop boxes to dissipate energy as the tailings drop approximately 160 vertical ft. The pipelines drawing water from a depth of approximately 120 ft would discharge into a mixing chamber anchored to the side of the fjord at a depth of approximately 35 ft, similar to that for a Wilson Arm disposal (see Figure II-12).



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TAILINGS TUNNEL PORTAL
AT BOCA DE QUADRA

SOURCE BECHTEL DWG. SK-C-203 DATE MAR 84

FIGURE III-10

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During the operation of the tailings disposal facilities, approximately 79,850 tpd of tailings would be discharged to Boca de Quadra based on an ore production rate of 80,000 tpd. Characteristics of the discharge facilities and monitoring programs would be similar to those for the Wilson Arm tailings disposal facilities.

After the inner basin has been filled to sill depth, U.S. Borax expects tailings to flow over the sill into the middle basin. If tailings do not flow over the sill, the tailings pipeline could be extended by 15,000 ft to the middle basin. This extension of the tailings line to the middle basin of Boca de Quadra may be installed after several years of operation if modeling shows the extension to be necessary. This pipeline would be a submerged high density polyethylene double-walled line with a leakage sensing system between the walls attached to the fjord wall approximately 15 ft below the mean lower low water (MLLW) level and 10 ft below extreme low water. The twin 24 in. diameter pipelines would be attached to concrete sleepers for support and ballast. The sleepers would be held in position by a cable anchored above the mean tide level. Spacing between sleepers would be 20 to 25 ft. The pipeline would be designed to drain by gravity in the event of a pipeline break or pump or power failure. A new outlet works identical to that described for the initial outfall location would be constructed for the extended line. The maximum probable spill from this extended line would be an additional 3,500 cu yd of tailings.

If the inner basin of Boca de Quadra is used for tailing disposal, the access road to the tailings tunnel portal at the Boca de Quadra end would connect with the small dock. The road would be 14 ft wide and 2,000 ft long. Grade would not exceed 12 percent. Clearing for the road may provide some materials needed for dock construction, such as rocks and logs. The road would be constructed in conjunction with earthwork for construction of the tailings discharge structures. The road would provide access from tidewater to the tunnel portal during construction and operation. Rock excavated from the tunnel would be placed in a disposal area adjacent to the portal and/or in the fjord, depending on final design. Up to 22 acres would be occupied by the dock, storage area, access road, tunnel portal, pipeline, and on land waste rock disposal area, extending from tidewater to about 230 ft elevation and with a lateral extent of about 1,500 ft. Leveled areas near the dock and at the tunnel portal would provide space for storage sheds, fuel storage tanks, on site sewage treatment, and a helipad. Drainage control structures would direct runoff and reduce the erosion potential.

For the Boca de Quadra tailings disposal option, a floating camp would be required. This camp would be used to house approximately 50 personnel required for the driving of the tailings tunnel. The camp would be operated for a period of 1-1/2 to 2 years. The camp would be self contained with no land based facilities except a potable water supply structure at a nearby unnamed creek and an incinerated refuse burial area. The camp would be owned and operated by the construction contractor.

Reclamation of the tailings disposal facilities at mine closure would be accomplished by recontouring, reseeding, and replanting of the surface pipeline areas. All pipeline and facilities installed in Wilson Arm would be removed and salvaged.

2. Middle Basin Boca de Quadra Tailings Disposal

This alternative has the same basic facilities as the inner basin tailings disposal project. However, rather than initially discharging to the inner basin of Boca de Quadra, the pipeline would be constructed to discharge to the middle basin throughout the life of the mine. If the tailings line is extended from the tunnel portal of the proposed project, two 24-inch diameter high density polyethylene pipelines would leave the transition structure at the tunnel portal and carry the tailings to the middle basin discharge point.

With a Tunnel Creek plant, the tailings tunnel could be realigned to go directly to the middle basin. Such a tunnel alignment would be approximately 1.7 miles longer and therefore more expensive than a tunnel alignment to the inner basin. The tunnel would pass under the Falsegate Creek basin but would not daylight in this area. Because of the length of this tunnel, a vertical shaft would be driven to the tunnel at Falsegate Creek to allow for tunnel ventilation and to serve as an escapeway. The tunnel portal at Boca de Quadra would be in the wilderness area. Areas for construction equipment and tunnel waste rock disposal would be required at the portals at Tunnel Creek and Boca de Quadra.

3. Alternative Tunnel Alignments

For marine disposal in Boca de Quadra from the Beaver Creek mill site, the total tunnel length as shown in Figure III-2 would be 23,700 ft. In addition, approximately 5,000 ft of avalanche shed would be required for the surface pipeline in Tunnel Creek connecting the two tunnels. Some realignments of the tunnels could be possible, although any extension of a tunnel would result in cost increases. The realignment of the tunnel shown in Figure III-3 would result in a tunnel portal below the Keta River estuary rather than at the estuary.

Alternative tunnel alignments are also possible from the Tunnel Creek mill site to the inner basin of Boca de Quadra. An alternative site 'C' is located approximately 3000 ft upfjord of the inner basin discharge point described in Section II of this Appendix.

4. Ocean Tailings Disposal

An alternative method of marine disposal is to discharge the tailings into the open sea. The tailings would be transported by pipeline from the mill site to the wharf, where they would be transferred to a barge and transported to sea for disposal. This method is technically feasible but has not been investigated in detail. Preliminary estimates indicate that this is prohibitively expensive, roughly 100 times the cost of submarine disposal to the fjord. Assuming it is

possible to completely dewater the tailings prior to discharge, about 80,000 tons per day would need to be transported. A minimum of two ships would be required and a provision would be required to discharge the tailings into the fjord during periods of unavailability of a ship. Due to engineering and economic problems with this alternative, it has been eliminated from detailed study.

5. On-Land Tailings Disposal at Tunnel and Aronitz Creeks

The on-land tailings disposal alternative involves the development of tailings dams and ponds in the stream valleys of Tunnel Creek and Aronitz Creek. This alternative would preclude the use of Tunnel Creek for the concentrator or the power plant. The conceptual on-land tailings facilities design indicates that two dam sites would be required to contain the expected volume produced over the proposed 55 year life of the mine as shown in Figure III-4 and III-6. The Tunnel Creek impoundment would be filled first, and then the Aronitz Creek impoundment would be developed if the Beaver Creek mill is selected. With a North Meadow mill the order would be reversed. The ultimate design heights and lengths of the dams are approximately 1,000 ft high, one mile long for the Tunnel Creek site, and approximately 780 ft high, 2/3 mi long for the Aronitz site. The Tunnel Creek dam would require approximately 133 million tons of rockfill. Over 73 million tons of rockfill would be required for the Aronitz Creek dam. The storage capacity for the Tunnel Creek site has been estimated at approximately 803 million tons, with 1,400 ac inundated by the tailings. The Tunnel Creek site would store an estimated 424,000 ac ft of tailings (including slurry water permanently trapped in the voids in the tailings) and 36,000 ac ft of surface water. The storage capacity of the Aronitz site has been estimated at 730 million tons with 1,300 ac inundated by tailings. The Aronitz Creek site would store 385,000 ac ft of tailings and 31,000 ac ft of surface water. Reservoir storage capacity of both sites would include storage of tailings above the dam crest by using the Thickened Discharge Method. This method involves depositing the tailings in a cone-shaped hill during the final years of tailings pond operation. Thickened tailings discharged from an elevated pipeline form a cone as it comes to rest at its natural angle of repose.

The on-land disposal option would require additional roads for access to the pipeline and tailings dams. This would involve construction of roads up Tunnel Creek and to the Aronitz Creek site. Access roads, and possibly wharf facilities, for workers, equipment, and supplies would be required at each dam site. For the North Meadow mill site, the access road and pipeline right-of-way to the Aronitz site would be along Hill Creek and the Keta River to reach the dam site. An extensive system of roads would also have to be developed to haul rockfill for the dams from the borrow areas. The necessary haul roads would be located within the area which would ultimately be inundated with tailings. In order to reach the borrow areas during the latter years of dam construction when tailings would fill the lower portion of the valley, the construction haul roads would have to be built on the steep valley sideslopes.

The rockfill dams for the tailings impoundment would be constructed in stages using the downstream construction method. Quarries for the rock would be located within the area to be inundated with tailings. At the start of construction a diversion tunnel would be driven. Upon completion of the tunnel a cofferdam would divert the stream through the tunnel. The dam foundation would then be stripped and prepared for dam construction. If necessary grouting would be performed. Construction of the dam would proceed with placement of the rockfill shells and filter zones. The spillway, a morning glory type, would be constructed with a connection to the diversion tunnel. The tailings pond decant would be over a crest and into a conduit paralleling the spillway conduit. It would also flow to the diversion tunnel. The decant crest can be raised or lowered by the placement of panels in the top of the decant conduit, enabling low flows to be maintained in drought periods. Upon completion of the first stage of the dam the diversion tunnel inlet would be permanently closed. Water would initially be totally stored behind the dam, then begin to flow through the decant structure when the first decant level is reached. The dam height would be progressively raised as additional tailings capacity is required. During each raise of the dam, the spillway and decant would also be appropriately raised. After completion of the raised morning glory inlet, the former inlet would be permanently blocked. The morning glory spillway type was selected due to its suitability for staged construction, however, it does have a drawback of potentially being plugged by large floating debris. Tailings impoundment maintenance would have to be performed to minimize this possibility. Construction of the tailings disposal sites would consist of clearing timber from 1,400 ac and 1,300 ac from Tunnel Creek and Aronitz Creek, respectively. Merchantable timber would be used on the project site or sold to a commercial operator.

At the Aronitz site a pumping facility would be required to move tailings up from the Keta Valley to the site. A means of emergency disposal, consisting of an emergency holding basin near lower Aronitz Creek, would be required in the event of a power failure or pump malfunction at the pumping station. Once the pumping is restarted, the tailings from the emergency basin would be pumped to the Aronitz Creek tailings disposal area. A backup power source could also be required to reduce the likelihood of the need for an ocean discharge. Frequent inspections and remote monitoring devices would be used to detect leaks or ruptures of the pipeline. Spill control for minor spills would be provided by routing the material to small sedimentation ponds. The maximum probable spill from a pipeline break based on a 30 to 60 minute detection and shutdown time would be 15,000 to 18,000 and 26,000 to 29,000 cu yd of tailings for the Tunnel Creek and Aronitz Creek lines, respectively.

The proposed dams would have upstream and downstream faces with a 2:1 slope. The upstream face would be covered with a 25 ft thick layer of tailings to provide a relatively impermeable membrane. The design would minimize seepage through the dam. The spillway design for each of the tailings dams would be based upon the probable maximum flood (PMF) calculated from probable maximum precipitation estimates. The

PMF would be accommodated by a combination of reservoir storage reserved for floods and spillway discharge. The proposed method of providing a new spillway inlet as the dam is raised would allow the dam to pass the probable maximum flood at all times, including during ongoing construction. Runoff from the natural areas above the tailings pond would be allowed to run into the tailings area. The reasons that perimeter collection and diversion ditches are judged infeasible are discussed below. The spillway decant system would be designed to provide an increment of storage between the maximum decant crest and the crest of the spillway, which would include a permanent 3,000 ac ft minimum pool for sedimentation and provision to store the volume of a 10-yr, 24-hr storm plus additional storage for a preceding period of flow exceeding the decant capacity. Since the proposed dams have not yet been designed in detail, detailed stability analyses have not been performed. During mining operations with the Beaver Creek mill site, the Tunnel Creek site would be used before the Aronitz Creek site. The Aronitz site would be used before the Tunnel site, if the North Meadow mill alternative is selected.

Diversion channels would normally be used to reduce surface runoff inflow to the tailings impoundment. However, at the Tunnel and Aronitz creek sites such channels have been judged to be infeasible for a number of site related reasons. The high precipitation characteristic of the area would require a very large diversion channel, approximately 20 ft wide at the base, flowing 15 ft deep for the 10-yr storm. This channel would have to be largely excavated in rock on steep slopes. Approximately 20 to 25 percent of the ditch length would be on slopes of 0.5 horizontal:1.0 vertical. The diversion channel could be blocked by avalanches, landslides, and normal debris that would be likely in these areas. Since the channel might be blocked during a critical runoff event, in order to assure the safety of the dam, the dam, storage area, and spillway would have to be constructed as if no diversion channel existed. Seepage from the channel could also affect the stability of slopes downhill from the channel.

Delivery of tailings from the Beaver Creek mill site would be by a 5,900 ft pipeline from the mill to a launder in a 12,700 ft tunnel to Tunnel Creek then via a 13,000 ft pipeline with spigots along the north side of the Tunnel Creek pond and across the upstream face of the dam. Tailings flow would be by gravity. Tailings would be placed to maximize settling time before the decant water reaches its outlet. When the Aronitz Creek site is in operation a 5,000 ft pipeline would extend from the tunnel outlet described above to a launder in an 11,000 ft tunnel to the Keta valley. A 16,500 ft pipeline would extend from this tunnel to the dam site where 13,000 ft of distribution pipelines and spigots would extend along the east side of the pond and across the upstream face of the dam. The Aronitz site would require 4 booster pumping stations, each with two 1,000 horsepower pumps to lift the tailings 150 ft each. The distribution pipelines at both the Tunnel and Aronitz sites would be in part in areas subject to avalanches. However, if the pipeline was ruptured by an avalanche the tailings would still flow downhill to the impoundments. For the North Meadow mill site tailings would be delivered to the Aronitz site by a surface pipeline and to Tunnel Creek through a second surface pipeline. The surface pipelines would have to be protected from avalanche hazards.

At the tailings impoundment water would be released through a decant structure to the natural drainage only after meeting best available technology (BAT) economically achievable and best conventional pollutant control technology (BCT) NPDES permit effluent limitations for a "new" discharger and meeting Alaska receiving water quality criteria. Dilution, settling, and decanting is proposed to meet these limitations; however, if further treatment is needed it would provided to meet the pertinent standards. Releases from the tailings ponds would consist of natural inflows plus water recovered from the tailings slurry minus any water withdrawn to meet process water demands. All releases would be uncontrolled as there are no gates or valves in the facilities. Releases from the tailings ponds would be made over the decant/outlet weir for flows up to the 10-year, 24-hour flood. Flows greater than this would raise the level of the pond until it begins to discharge through the spillway morning glory inlet. The sediment removal process would be controlled by the volume of water in the pond. If necessary, the sedimentation process could be regulated by installing precast concrete members to raise the crest of the decant weir to increase the detention time of the releases. A longer detention time would improve the sedimentation process.

In the case of the Tunnel Creek impoundment decant water would be pumped back to the mill for reuse as process water. The decant water would consist of natural runoff from the basin upstream of the tailings dam and water which separates from the tailings slurry. Approximately 20 to 30 percent of the water in the tailings slurry would remain trapped within voids in the tailings solids deposited in the pond. Water to be used to meet plant demands would be withdrawn from the pond by submersible pumps located near the decant conduit. The return water pipe and pumps would be installed along the tailings pipe right-of-way. Natural runoff water and water from the tailings, if pumped to the mill, would completely satisfy the water requirement for the mill when the Tunnel Creek impoundment is in operation. Because of the much greater distance, elevation differences, and resultant cost, water would not be pumped back to the mill from the Aronitz Creek site and, hence, alternate water supplies such as the Wilson River well field would have to be developed during the period of use of the Aronitz Creek impoundment.

Compliance with "New Source" NPDES permit limitations, which means zero discharge and complete recycling of water, was analyzed but judged infeasible due to several factors. Since, as explained previously, diversion of natural runoff is not feasible, the high volumes of natural runoff from the average annual precipitation of 150 in. would also have to be recycled. This volume of water would exceed plant demands. At the Aronitz Creek site, recycle water would have to be pumped a long distance against a significant elevation difference to the mill site, resulting in very high costs.

Reclamation of the tailings disposal areas would consist of stabilization and revegetation without the addition of topsoil, since there is no adequate source. Repeated fertilization would probably be required. Since maintenance free reclamation would probably not be possible, the owner/operator might be required to set up a permanent fund during operations which would generate revenues for maintenance of tailings dams. Even so, whatever revegetation is feasible should be performed. During the last 10 years of a pond's operation tailings would be placed by the Thickened Discharge Method to maximize reclamation potential by improving drainage and consolidation. Several months prior to abandonment of an area, appropriate neutralizer, fertilizer, and seed would be added to the tailings at the discharge. Appropriate methods of revegetation would be refined during a revegetation experiment program that would be conducted at the mine. After storage of new tailings and water is no longer required, the spillway and decant outlet would be permanently plugged and the dam breached just above the tailings level to ensure that it no longer retains water. The crest of the breach would be as long and level as feasible and would be protected against erosion with large rock. The face of the dam below the breach would be made into a spill channel with large rocks providing erosion protection.

6. Other On-Land Tailings Disposal Sites

Small quantities of tailings, less than 10 years production, can be placed in several small valleys but in addition to Tunnel and Aronitz creeks only Falsegate Creek and an unnamed tributary of the Wilson River about 1 1/2 miles upstream of the confluence of the Wilson and Blossom rivers appear to offer storage on the order of one half of the projected needs. Falsegate Creek was eliminated from detailed consideration because it was the most expensive and offered no advantages. The Wilson tributary valley appears less suitable environmentally because runoff could severely affect salmon spawning in the Wilson River. Thus no other on-land disposal areas were identified.

7. On-Land Tailings Disposal with Ultimate Backfill to Pit

In this alternative tailings would be returned to the pit at the termination of mining. Because of engineering constraints of the open pit mine, tailings cannot be returned directly to the pit after milling since in open pit operations the entire pit is active and cannot be reclaimed until the end of operations. Thus tailings would be stored in tailings ponds as described in the on land disposal alternative above. Upon termination of mining, tailings would be removed from the tailings ponds and replaced in the pit. Due to the expansion in volume of tailings as compared to the native rock before mining, all tailings cannot be replaced in the pit. It is estimated that only the contents of one impoundment can be stored in the pit. The other tailings impoundment would have to remain in place. Because of the extremely

high cost of this method ($250 million dollars in additional capital costs and $190 million per year for 30 years after mining above the on-land disposal option), engineering difficulties, and the lack of environmental advantages (the on-land tailings areas would still be impacted throughout the 55 years of the mine life), this alternative has been eliminated from detailed study.

G. HOUSING ALTERNATIVES

Three housing alternatives for the operational phase have been evaluated for the project:

1) Townsite Option - development of a new, self contained community near the Quartz Hill mine and processing plant to provide both single status and family status housing and all related services;

2) Phase-In Option - a time-phased development beginning with the commute option. A townsite would be developed in increments over several years, with full development coordinated with expansion of mine facilities and production, and completed after 4 to 6 years, at which time single status and family status housing and all related services would be available at the townsite; and

3) Commute Option - development of single status housing facilities at the Quartz Hill site with workers commuting to and from Ketchikan on a regular rotation.

The third alternative was chosen as the proposed action, and is described in Section II.F. If a townsite is developed, additional construction workers above the number shown in Table II-9 would be needed to construct the housing and support facilities. The number and timing of additional workers needed for the "townsite" and the "phased-in townsite" alternatives are presented in Table III-2.

1. Permanent Townsite

The new community component, whether developed initially or incrementally in several years, could be developed in one of several alternative sites. Similar services and community facilities to those described below for the Bakewell townsite would be provided for any townsite, with a few appropriate exceptions.

Bakewell

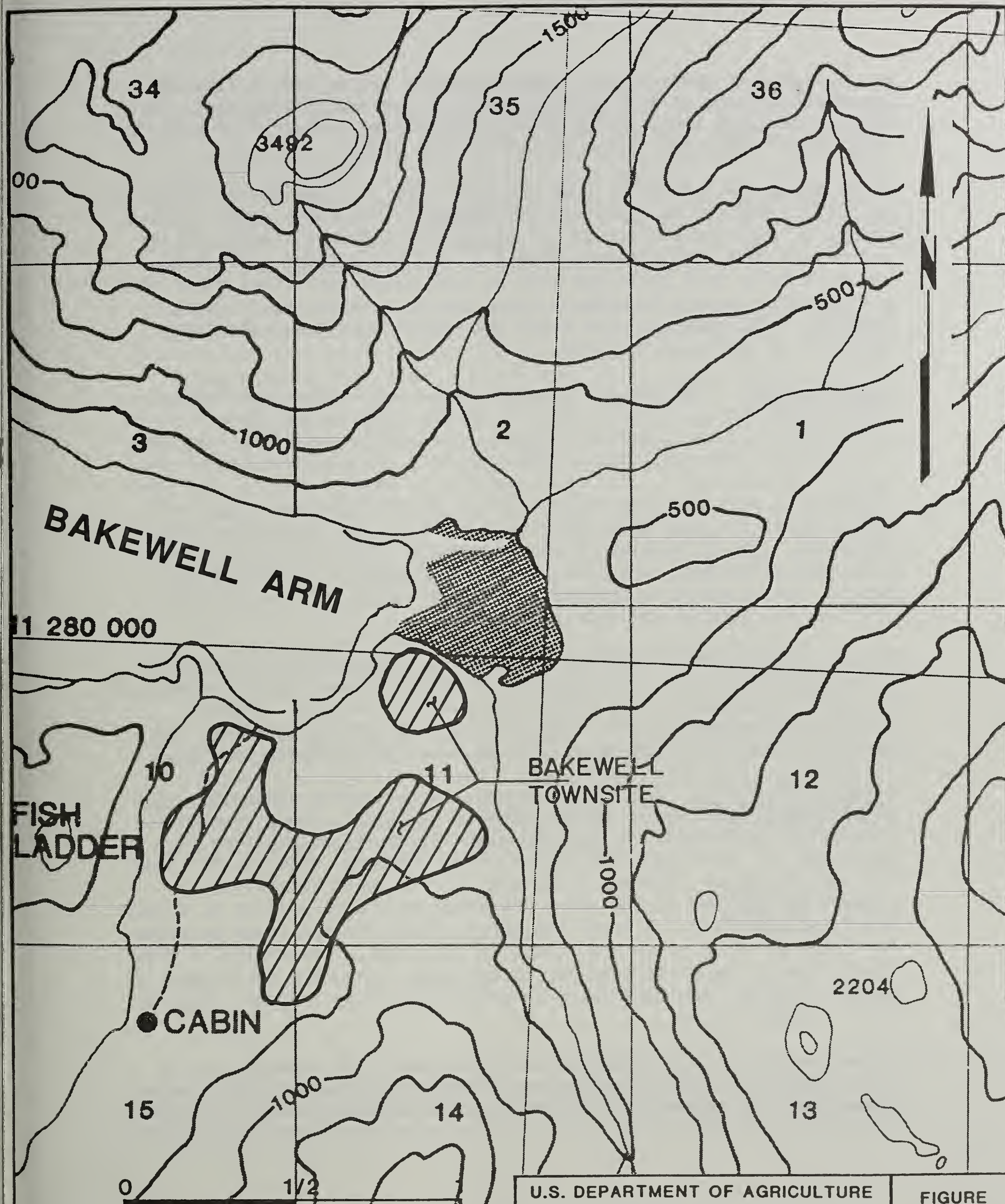
A permanent community at the Bakewell Arm site (Figure III-11) would occupy up to 200 acres east of Bakewell Creek. Housing facilities would include a mix of housing types to meet a variety of needs and preferences, such as single family homes, apartments, mobile homes, and houseboats.

TABLE III-2

ADDITIONAL WORKFORCE FOR TOWNSITE OPTIONS

Year/Quarter		Construction Workers	
		Townsite	Phased-In Townsite
Pre-Operation			
-2	1		
	2	100	
	3	200	
	4	250	
-1	1	250	
	2	250	
	3	200	
	4	100	
Startup			
1	1		50
	2		60
	3		70
	4		100
2	1		100
	2		100
	3		100
	4		100
3	1		100
	2		100
	3		100
	4		100
4	1		100
	2		70
	3		60
	4		50

Source: Schlessinger 1984.



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BAKEWELL TOWNSITE LOCATION MAP

SOURCE ENVIROSPHERE DATE NOV 83

FIGURE III-11

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At the Bakewell townsite the community would evolve from a floating construction camp to a land-based camp to a permanent townsite. This transition would allow flexibility in developing a mixture of housing types and should permit the best efficiency of building use.

Floating Camp - A floating camp would be used to house approximately 50 personnel required to construct the Bakewell land based camp. Initial occupancy would take place at the beginning of townsite construction and extend until the completion of the land based camp. This camp would be fully self contained with no land based facilities other than a fresh water supply from Max's Creek and an area for solid waste disposal. The camp would be owned and operated by the contractor selected to construct the town.

Townsite Camp - The Bakewell townsite camp would house approximately 130 construction personnel required to construct the townsite. Construction of the camp would begin while the Bakewell floating camp is in place. The camp would remain in place for the duration of the townsite construction. The camp could be of modular design, but some elements, especially support facilities, may be designed to satisfy requirements of both the construction workers and the permanent town residents. The potable water supply would be drawn from Max's Creek. A maximum withdrawal rate of 6 gpm is anticipated to satisfy camp needs. Sewage would be treated at and discharged to Bakewell Arm. Solid waste disposal would be provided.

Muskeg areas would be modified as needed for development by partial filling (surcharging) and compaction. Electric power would be supplied by diesel generators. The camp would include sleeping, kitchen, dining, and recreation facilities and would be project owned. Camp operations would be contracted to a professional catering service.

Permanent Townsite - The town would be a full service community. Its support facilities would include schools, a clinic, shopping center, recreation facilities, marina, and a wharf capable of handling personnel and supplies. The town would be compact, reducing the need for private cars. Internal roads and streets would be provided connecting the town to the wharf and barge and ferry service to Wilson Wharf and Ketchikan. A local bus service would be developed to allow for internal circulation and access to the wharf. Eventually, a road connection to the plant site may be developed along the north shore of Bakewell Arm and the east shore of Wilson Arm or by a tunnel (Figures III-1 through III-4).

Potable water for the community would be drawn from a diversion in Max's Creek, and piped to the water treatment plant. The daily water demand for the community is estimated to be less than 0.5 cfs. A small diversion structure would be built on the creek to provide submergence

for the pump intakes. Raw water would be pumped to an at-grade, raw water storage tank. The tank would be adjacent to a water treatment plant building containing two 100-gpm package treatment units connected in parallel which would clarify and disinfect the water. The water supply system would be designed to comply with all applicable state water supply regulations. A clearwell would connect directly to the distribution system. A single water distribution system would provide both potable water and fire water, deliver 80 to 100 gallons per capita per day and include storage of about 500,000 gallons.

The sanitary sewer collection system would include two gravity flow mains, with collected flows from low lying areas pumped to the gravity mains, and the mains discharging to an equalization pond. A sewage treatment plant with modular treatment units, and a nominal capacity of 200,000 gallons per day (gpd) would be constructed. Treatment would consist of equalization, contact stabilization, and disinfection. Treated effluent would be discharged into Bakewell Arm and the sludge periodically removed and trucked to an incinerator for disposal.

The sewage treatment plant and the community waste incinerator would be adjacent to each other on the same site. The community's municipal solid waste would be collected by a conventional garbage truck from 2 yd^3 debris boxes and burned in an incinerator sized to burn 6-8 tons in 8 hours. A fuel oil tank with containment dike would be provided. Ash would be transported to the mine's waste rock disposal area by boat or, if the Bakewell-Wilson Arm wharf road is built, by truck. Non-combustible material would be disposed of at the project site in an approved area or transported to an appropriate off-site disposal area.

The community power plant would consist of four 1,500 kW diesel generators contained in a building of approximately 4,000 square feet. The number and size of the units allows for maintenance and other outages, and for peaking capacity roughly twice the average demand. Power would be distributed in underground lines. The schedule for installation of the diesel generators is:

Unit(s) No.	Year	Approximate Community Size (Persons)
1 & 2	-2	700
3	1	900
4	2	2,000

Two to three months storage of No. 2 diesel oil would be provided. The storage requirement are based on an average demand of 1.25 kW per capita. Two storage tanks would be provided to meet the ultimate year 1990 community requirements.

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In the event that a road is constructed from the town to the Wilson Arm wharf area, an overhead transmission line would be installed to transmit power to the community from the central power plant located at the Tunnel Creek site. The community diesel generating station would then remain for standby service.

If a road between the Bakewell townsite and the Tunnel Creek facilities or the Wilson Arm Wharf is built, it could follow the perimeters of Bakewell Arm and the east shore of Wilson Arm or it could go through a tunnel between the north shore of Bakewell Arm and Wilson Arm south of the wharf. The road surface would be gravel, the roadbed 36 ft wide and about 9 miles long (about 6 miles by the tunnel route). Either route would require a significant amount of rock blasting, and the rubble would be dumped into the fjord. Falsegate Creek would be crossed by a 100 ft long bridge. Five smaller creeks would be bridged, and culverts would be placed in wet areas to allow drainage. Clearing of the corridor would include sale of merchantable timber and disposal areas for slash. Snow would be plowed from the road areas as needed.

Townsite preparation would require removal of forest and stabilization of muskeg. An estimated 60 acres of the proposed townsite is underlain by muskeg varying in depth from 4 to 12 ft. It is anticipated that only a limited portion of the muskeg would be excavated and disposed off site. The remaining muskeg areas would be compacted in place through draining and subcharging (partially filling with rock). Excavated areas and depressions caused by the compaction of muskeg would be back-filled with excavated material taken from areas within the townsite requiring cuts. Other sources of gravel, sand, or fill have not been identified. The actual volume of muskeg to be excavated could differ substantially from that assumed, but would not be known until detailed soils investigations and tests have been performed. Some buildings located on compacted muskeg may be built on piles. Areas without muskeg or with shallow muskeg would be preferred as development areas.

The acreage required for the townsite would be leased to U.S. Borax by the Forest Service for the duration of the Quartz Hill project. Any land transfers by the Forest Service to other ownerships would have to be consistent with the provisions of ANILCA.

Other Alternative Townsites

Several alternative townsites were considered during the Bakewell townsite selection process. Table III-3 lists the sites which have been evaluated and compares them on the basis of several criteria. Two or possibly three sites are considered possible alternative townsites to accommodate various project development concepts, and they are discussed below. Other sites evaluated, including Aronitz Creek, Wilson II, III and IV, Tunnel Creek, Fuel Cache, and East Knoll are not considered to be reasonable alternatives.

TABLE III-3

COMPARISON OF TOWNSITE ALTERNATIVES

Townsite	Available Space (acres)	Natural Hazards	Topography Adaptability	Access	Microclimate	Aesthetics	Recreation and Amenities	Compatibility with Development Options	Environmental Concerns	Deserving of Further Consideration
Wilson I	120	none	marginal; much earth-work	good; bridge needed	fair exposure, elevation	fair view; odor problem possible	good	yes	riparian	yes
Wilson II	ca. 250	flood	marginal; much fill	good; bridge needed	fair exposure, good elevation	fair	good	yes	estuary, floodplain	no
Wilson IIa	ca. 200	none	fair	good; bridge needed	fair exposure, elevation	fair to good	good	yes	estuary, riparian	yes
Wilson III & IV	265		fair	good; bridge needed	marginal exposure	fair	fair	yes	riparian	no
Tunnel Creek	240	flood	fair	excellent	poor exposure	poor	good	no	riparian	no
Fuel Cache	small		fair, muskeg, steep	fair	poor elevation	good view	fair	yes	-	no
East Knoll	small		fair	fair	poor exposure	good view	fair	yes	-	no
Bakewell	250	none	good, some muskeg	fair; more distant	good elevation, and exposure	good view, good overall	good	yes	-	yes
Keta 1	120	flood	marginal	OK with Keta access only	good elevation, marginal exposure	fair	good	partly	estuary	no (only with Keta road)
Keta 2 (Aronitz)	115	avalanche, flood	marginal	OK with Keta access only	good elevation, marginal exposure	good	good	partly	-	no

Source: Forest Service 1981a with modifications.

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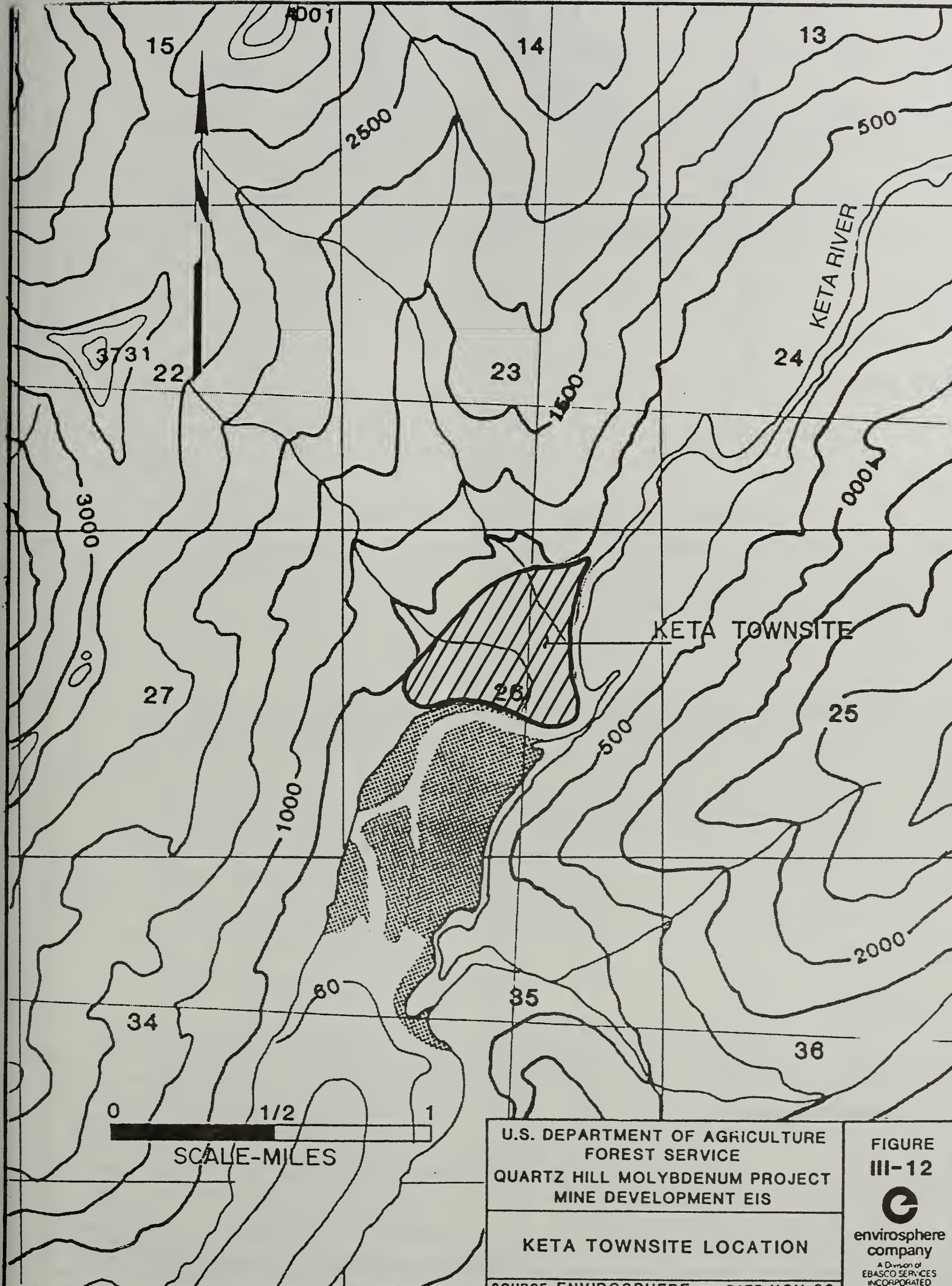
Keta - If a project development concept were selected that would place a road in the Keta River drainage, and especially if the Blossom access were closed, then the Keta townsite becomes an alternate. The townsite is adjacent to the Keta River estuary (Figure III-12), and the wharf location would be near the mouth of Aronitz Creek. Potential drawbacks for this townsite include its limited size, proximity to avalanche paths, high winds, and proximity to and possible encroachment on the floodplain. Some development would probably occur near the wharf, especially because there is little room for expansion of the townsite. The town would occupy 120 acres (Figure III-12). The water supply would be drawn from one of the two small creeks north of the townsite, and the support services and facilities would be similar to those described for the Bakewell townsite, including a sewage treatment plant with discharge to Boca de Quadra, diesel powered electricity generators (possibly located near the wharf), a marina, television and telephone service, and a solid waste incinerator.

Aronitz Creek - The Aronitz Creek townsite was not chosen because of avalanche and rock fall dangers, potential flooding and limited exposure to the sun.

Wilson I - The primary alternative to the Bakewell townsite is the Wilson I townsite near the confluence of the Wilson and Blossom rivers. Rather extensive excavation and filling would be required to accommodate the townsite. Otherwise, an unusual number of multiple level apartment buildings would be required, thus lowering the flexibility of housing choices. The town would occupy 120 ac (Figure III-13).

Wilson IIa - A Wilson IIa site on the west side of the Wilson River (Figure III-13) would require an extensive amount of fill to elevate the site above the floodplain. The site could alternatively be located on the westernmost part of the valley on slightly higher ground. The floodplain site encroaches on part of the estuary. The west-side valley site would occupy the area most feasible for an airstrip.

Neither Wilson I or IIa townsites would have direct access to salt water for a marina or related facilities. Nearby creeks would be tapped for water, and the other services and facilities would be provided as described for the Bakewell townsite, including a sewage treatment plant with discharge to the Wilson River, electric power from onsite diesel generators or from the central power plant via transmission lines, solid waste disposal in an onsite incinerator or at the incinerator near the processing plant, and television and telephone service. Both townsites would be connected by road with the mine access road via a bridge over either the Wilson or Blossom rivers.



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KETA TOWNSITE LOCATION

SOURCE ENVIROSPHERE DATE NOV 83

FIGURE III-12

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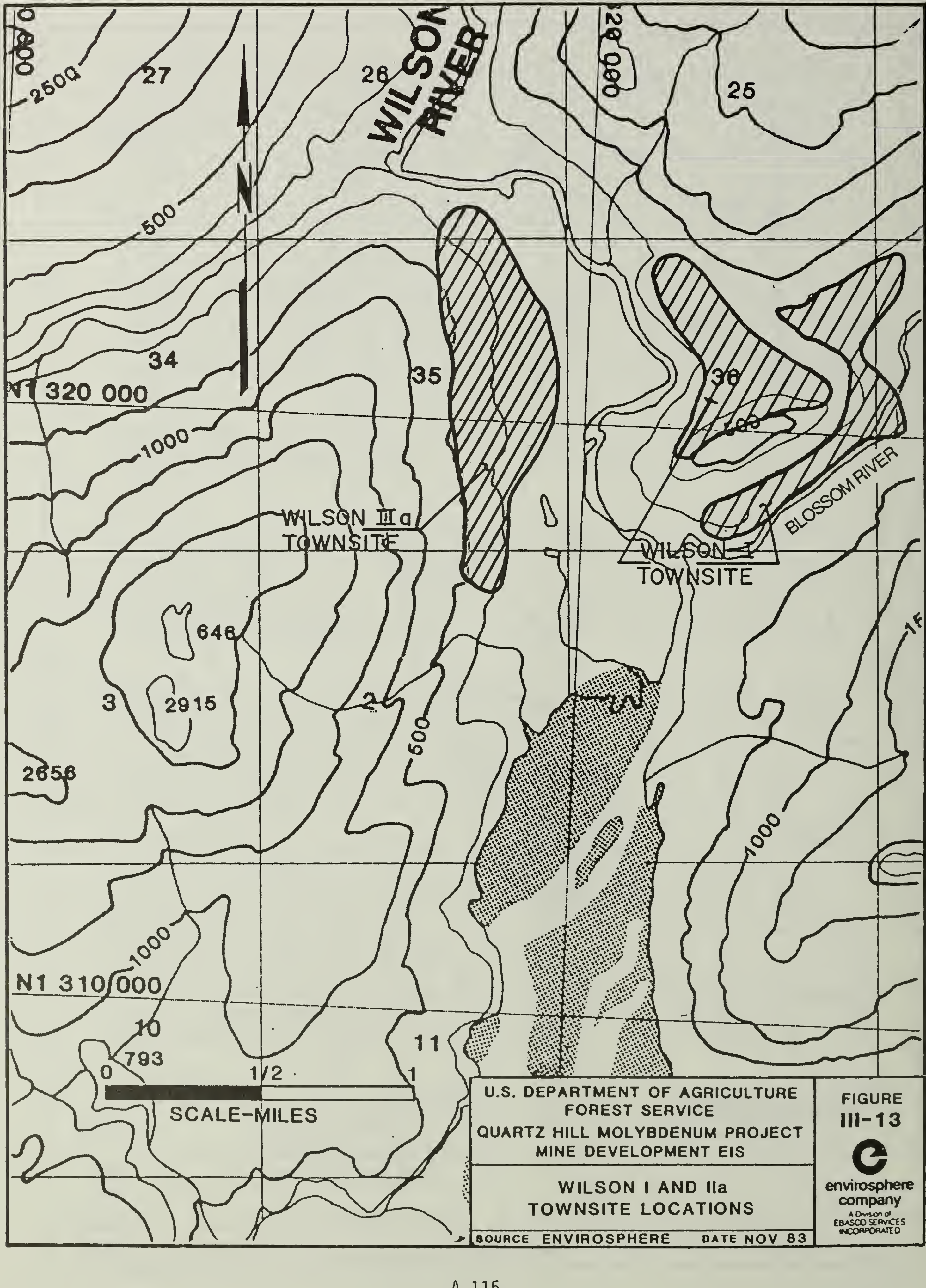
WILSON RIVER
2500
27
26
25
500
N
34
35
36
N1 320 000
1000
WILSON IIa TOWNSITE
WILSON I TOWNSITE
BLOSSOM RIVER
646
3
2915
2
500
2656
1000
1000
N1 310 000
10
793
11
0
1/2
1
SCALE-MILES
U.S. DEPARTMENT OF AGRICULTURE
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MINE DEVELOPMENT EIS
WILSON I AND IIa
TOWNSITE LOCATIONS
SOURCE ENVIROSPHERE
DATE NOV 83
FIGURE
III-13
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Phased Townsite Development

Any of the above townsites could be phased in as the project expands. Initially, most workers would commute from Ketchikan. The townsite would be developed gradually, with full town development completed in about 4 to 6 years after the start of production. Initially, the permanent community would house operating staff on single or family status. The town would grow over the development period to a full service community of operational and service personnel and their families.

H. OTHER SUPPORT FACILITY ALTERNATIVES

1. Wharf Alternatives

Boca de Quadra Wharf

If the mine access road is built in the Keta River drainage, the wharf would be built near the mouth of Aronitz Creek (Figures III-4 and III-5).

The wharf facilities would include a warehouse, office building, receiving facilities, ferry and crew-boat docking facilities, floating marina, seaplane float, barge ramp and unloading facilities, fuel storage tanks and spill control facilities, sewage treatment plant, heliport, vehicle parking area, and maintenance facilities. The sewage treatment facility would discharge effluent to Boca de Quadra at a rate of 400 gpd. The water supply would be drawn from Aronitz Creek at a withdrawal rate of 400 gpd.

The wharf facilities would occupy 6 acres, including both areas of fill and a wharf and dock area over water supported by pilings. Construction crews would be housed in a floating camp at the wharf.

The wharf would be the key access point for all personnel, equipment, and supplies, and for shipping out the molybdenum concentrate. Certain materials, such as reagents and fuel, would be handled and stored by special procedures because of the potential dangers and impacts of spills. Snow and ice control would be essential. Snow would be removed by snowplow and would be dumped into Boca de Quadra or hauled to a disposal area. Ice would be controlled by tugs and barges which would keep navigation channels open.

Up-Fjord Location for Wilson Arm Wharf

This alternative involves the location of the wharf facilities up-fjord (north) of the present wharf rather than down-fjord (south) as envisioned in the proposed project. All facilities would be the same as for the proposed project.

2. Access Road Alternative

The primary road alternative lies in the Keta River drainage. This component is associated with two of the alternative development concepts discussed at the beginning of Section III.

The lower end of the Keta road alternative begins at a marine facilities site on the east side of Boca de Quadra near its head (See Figures III-4 and III-5). It runs along the southeast side of the fjord and the Keta River tidelands, crosses the Keta River and follows the Keta River floodplain to a point near the confluence of Hill Creek and the Keta River. The road then ascends Hill Creek Valley along the southwest side to the confluence with White Creek. The road then follows Hill Creek Valley to the North Meadow mill site. The total length of the road is slightly over 10 miles.

The road at its lower end would require bridges across Aronitz Creek and the Keta River. It would also cross about 500 yards of tide flats at the river mouth. The road would be placed above the 100-year floodplain in most areas. After leaving the Keta River Valley, the road follows the steep southwestern side of Hill Creek Valley and crosses six major avalanche tracks. Special roadway design such as tunneling or other measures would be required to protect the road, provide year-round use, and reduce hazards to users and equipment. Approximately 4,000 ft of tunnel, 24 to 26 ft in diameter would be utilized to avoid the avalanche areas. The tunnels would be sized to allow passage of the necessary mining and construction equipment.

If the Keta access route is selected, the present bulk sampling access road along the Blossom River route would be reclaimed after completion of the new Keta road. Reclamation would consist of excavating and removing culverts allowing for open ditch drainage, removing bridges, removing other facilities including the Wilson Arm wharf, and seeding the road bed.

Access road options for the Bakewell townsite and Wilson townsite alternatives are discussed in Section III.H of this Appendix.

3. Electric Power Supply Alternatives

There are two alternatives to the proposed power supply plan; alternative fuels for the combustion turbines, and an alternative power supply. These alternatives are discussed below.

Alternative Fuels

The primary fuel alternative to No. 2 distillate oil is natural gas. Other alternatives include crude and heavy oils. These fuels may increase costs of operation due to oil purification and scrubbing requirements. They would also increase emissions due to their higher sulfur, nitrogen, and ash contents, unless suitable scrubbers are provided.

Use of propane was considered, but was eliminated from further consideration due to engineering and economic considerations, including the unavailability of propane in suitable quantities at the site.

Use of natural gas as a fuel is desirable from an environmental perspective because it would substantially reduce air pollutants and eliminate the need for flue gas scrubbing and associated waste disposal. However, natural gas is not available at this time in the project vicinity. Providing natural gas to the site would require construction of a utility corridor which would traverse rugged terrain, including a portion of the Misty Fiords National Monument Wilderness Area. Alternative corridor alignments have not been formulated at this time. Because the availability of natural gas from Canada is uncertain, and because the feasibility of the utility corridor has not been established, U.S. Borax is proceeding on the basis that the Quartz Hill power plant would be fueled by low-sulfur oil. Planning based upon natural gas would present a substantial risk that fuel may not be available for the development. However, U.S. Borax may seek necessary approvals for a utility corridor should natural gas prove feasible in the future. The current design does not preclude the use of natural gas if and when it becomes economically available.

Alternate Technologies

Onsite nuclear, coal, and hydropower technologies were rejected earlier as not being feasible.

Transmission Intertie

A transmission line intertie to acquire Canadian power from Kitsault, British Columbia was also considered. This alternative is not being considered further at this time. If a transmission line is considered in the future, a separate NEPA process would be required. Consideration is currently being given by state and local entities to a transmission intertie system that would connect several load centers and power generation sources in Southeast Alaska. Evaluation and discussions are at a prefeasibility stage.

Reliance upon these supplies would not totally preclude construction of an on-site generating facility. Scaled-down on-site generation would be required to maintain essential equipment in the event of transmission line failure. On-site generation would not be designed to be sufficient to permit continuation of concentrator and mining operations during a power failure.

Diesel Powered Generators

Large, slow-speed diesel units can be installed to meet the projected 100 MW load. Such units have high (90+ percent) levels of reliability. They can be operated on heavy and light oils, but not natural gas; the experience with the latter fuel is not available. They are reasonably efficient (about 34 percent) having heat rates of about 10,000 Btu/kWh. Diesel units exhibit great flexibility in meeting part loads efficiently; thus they are desirable in remote locations.

Diesel units are less economical than combined cycle units when base loaded and operated at the scale (75-100 MW) contemplated here. About half of the heat rejected during operation is hot water from the water jacket used to cool the engine. This water is practically useless in the generation of additional power, given the current state of technology. This contrasts with the combustion turbine, where all the heat is rejected in highly useful form. The diesel unit cannot approach the efficiency of the combined cycle system. More fuel must be consumed at a significant penalty. Additionally, airborne emissions are increased proportionately. In addition, the application of SO_2 scrubbers to serve the diesel engines may introduce further problems as this technology has not been tried to date.

Medium speed diesel engines were eliminated from detailed consideration due to their inability to use heavy oils in a cold climate and the large number of units required. High speed diesels were not judged feasible since they are designed for light duty and are not suitable for continuous service in a power plant.

4. Water Supply Alternatives

Alternative water supply sources have been identified for the Quartz Hill project. The water supply alternatives were selected to be suitable for a continuous mineral processing operation, with particular attention to seasonal and annual low flow periods. Criteria used in the selection of potentially feasible water supply alternatives are (1) reliability, (2) cost effectiveness and (3) major environmental impacts.

In order for an alternative to be potentially feasible the water supply must be a reliable source for continuous operation of the flotation process and the power plant. Losses in revenues due to shutting down the facilities because of inadequate water have been estimated by U.S. Borax to be in excess of $1,000,000 per day at ultimate capacity depending on the market price of molybdenum.

Factors that could affect the reliability of water supply sources are as follows:

- o Quantity - The sources should provide the plant water demand even during seasonal limitations such as extreme dry year low flows and other weather influences.

- o Quality - This has to be consistent so as not to create upset process conditions that would result in molybdenite product losses and reduced revenue.

- o Operability - A system is not practical if excessive operator attention is required. The use of complex components for systems controls or instrumentation is an example.

- o Maintainability - Components should be readily accessible for maintenance during all weather conditions. If regular maintenance requires excessive shutdowns, costly duplicate facilities would be required.

- Technology - Known and proven technology and equipment must be used to assure viability of the supply, and achieve acceptable risk levels for project investment.

The cost effectiveness of water supply alternatives is related to both capital and operating costs. Capital costs are typically affected by engineering design, constructability, topography, access, natural risks, such as landslides and avalanches, and facility replacement needs. Energy requirements, accessibility for operation and maintenance, and personnel needed for operations and maintenance determine the operating costs of an alternative.

Each of the water supply alternatives has also been chosen to avoid environmental "fatal flaws", although more specific environmental impacts are addressed in this EIS.

Wilson River Well Field

This supplemental water supply system alternative, with a capacity equivalent up to the maximum plant demand of 16,000 gpm, would include a well system and a pipeline to the mill. Approximately 32, 8-inch diameter wells would be located along the left bank (viewed downstream) of the Wilson River between a large unnamed tributary entering from the west and the confluence of the Blossom River. The wells would be located a minimum of 50 ft from the OHWM. A 30-inch diameter pipeline and booster pumping plant would be constructed to convey the water to the plant site. The pipeline and access road would parallel the left bank of the Wilson River, crossing the Blossom River at its mouth and connecting to the mine access road.

Mine Drainage

Annual drainage from the mine site, including runoff and groundwater discharge to the pit is estimated to be approximately 12,100 acre feet per year, when the total area of the pit is developed. Since this flow would not meet total plant demand, it would be only a supplemental supply to reduce demands on other sources. These flows could be collected, treated, and made available for reuse at the plant site. Water conveyance to the Tunnel Creek plant site would likely be by a pipeline contained within the ore conveyor tunnel.

Although at ultimate pit development the average flow from the pit would be nearly 50 percent of plant demands, several factors make this source infeasible as a viable water supply source. In the early years of plant operation, only a small area of pit would be opened resulting in a much lower available water supply from the drainage area runoff and groundwater inflows. Thus, since the mine drainage would not meet full plant demand, particularly in the early years, other water supply systems would still need to be developed, such as on Tunnel Creek. Because there would be a lack of sites adjacent to the mine pit for storing storm flows for later conveyance to the plant, peak storm flows would have to be conveyed immediately to the Tunnel Creek storage

reservoir. A system to convey instantaneous peak runoff flows would require substantial expense for the requisite large pumps and pipelines. Since runoff events at the open pit would tend to coincide with runoff events in Tunnel Creek this additional water supply would be available primarily when sufficient water is already available in Tunnel Creek and would produce little or no flow when critical low flows are occurring in Tunnel Creek. In addition, although feasible, water collection and pumping installations would complicate the mining operations. For these reasons the mine drainage was eliminated from detailed study as a water supply source.

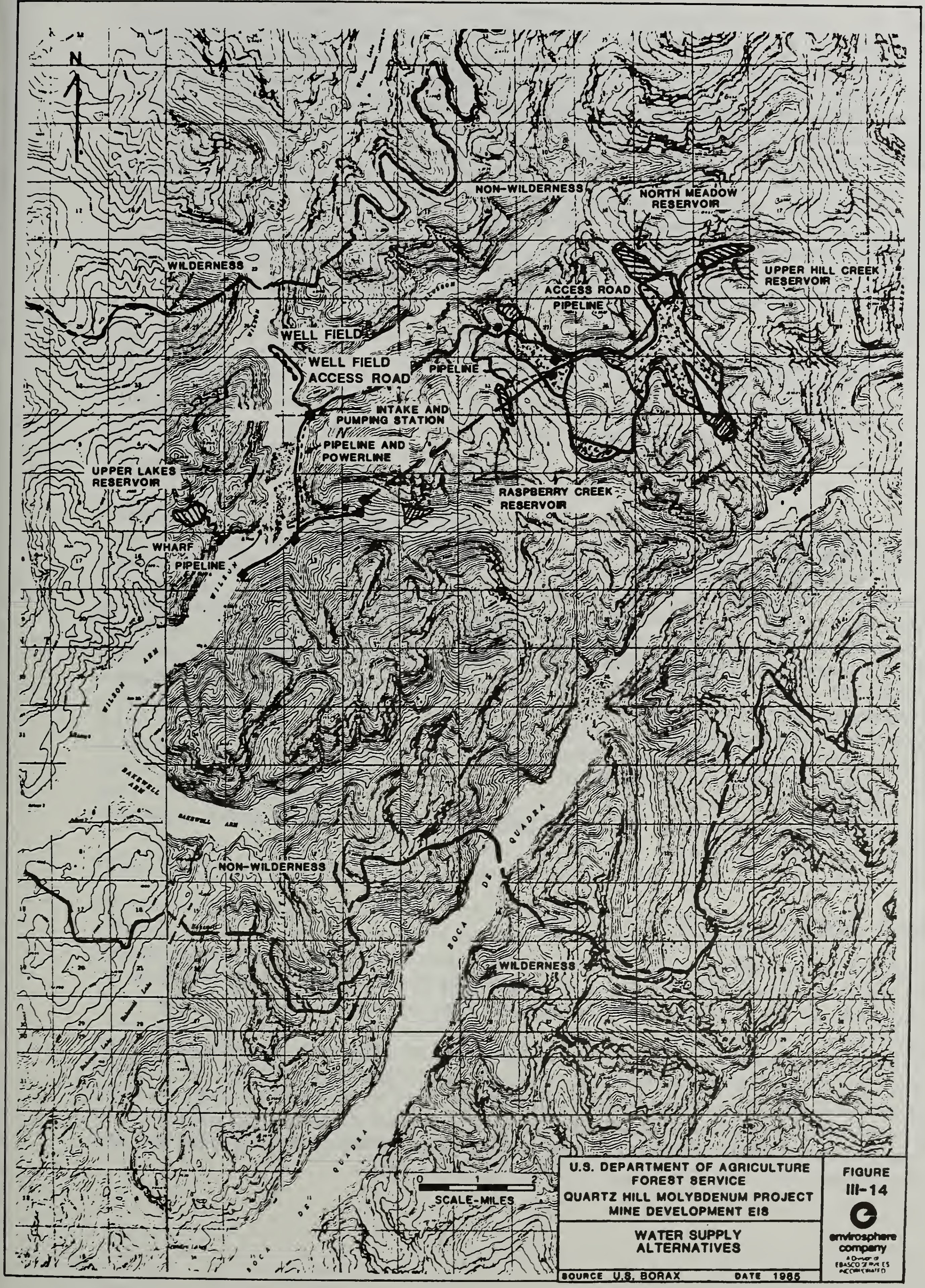
Water Quality Control Facilities

The proposed water quality control facilities could provide some of the process water supply. However, use of these dams for dual purposes as water quality control/water supply facilities would involve redesign of the dams and would not eliminate the need for other water supply sources. Present plans are to operate these reservoirs almost empty in preparation for a 10 year storm, therefore very little water would be available most of the time. Initially, any water supply system related to these dams would rely on the Upper Beaver Creek dam with its limited drainage areas of 1.6 mi^2. When the Lower Beaver Creek and Hill Creek dams are constructed, the drainage areas of the dams are still insufficient to meet plant demands during low flow periods. Thus, both Tunnel Creek and a supplemental source of water would still need to be developed. As with the mine pit drainage, seasonal timing of water availability from these basins would correspond closely to that of Tunnel Creek and, thus, would provide little net benefit. Additional facilities that would be required to utilize these sedimentation dams for water supply purposes would include increasing the height of the dams to provide a water supply pool, pumping plants ranging in size from 340 hp for the Upper Beaver Creek dam to 4,200 hp for the Hill Creek dam, pipelines from the dams to the plant and an enlarged conveyor tunnel to accommodate the pipeline.

Raspberry Creek Reservoir

The annual storable runoff from Raspberry Creek would be insufficient for the ore processing and power plant facilities water needs. The location of this reservoir is shown in Figure III-14.

Based on the available drainage area which can be impounded (1.37 square miles) and an estimated average annual runoff of 10.8 cfs per square mile, the mean annual discharge and the 7 day 10 year low flow at the point of potential impoundment on Raspberry Creek are estimated to be 14 cfs and 0.3 cfs, respectively. There are several other disadvantages to this site. Due to its nigh elevation, no appreciable flow into the reservoir can be expected during the cold dry winter months. Therefore, reservoir capacity must be increased to satisfy demands during this period. Freezing temperatures will also adversely affect valves and controls. The steep canyon on Raspberry Creek results in a low ratio of water storage to dam volume. If a Tunnel


N
NON-WILDERNESS
NORTH MEADOW
RESERVOIR
UPPER HILL CREEK
RESERVOIR
WILDERNESS
ACCESS ROAD
PIPELINE
WELL FIELD
WELL FIELD
ACCESS ROAD
PIPELINE
INTAKE AND
PUMPING STATION
PIPELINE AND
POWERLINE
UPPER LAKES
RESERVOIR
RASPBERRY CREEK
RESERVOIR
WHARF
PIPELINE
NON-WILDERNESS
WILDERNESS
BOCA DE QUADRA
0 1 2
SCALE-MILES
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
WATER SUPPLY
ALTERNATIVES
FIGURE
III-14
envirosphere
company
SOURCE U.S. BORAX
DATE 1985

Creek mill site is selected, in order to avoid major mining traffic, the pipeline will be directed to the primary crusher building and then run through the conveyor tunnel to the Tunnel Creek concentrator. This will create engineering and construction problems, substantially add to tunnel costs and introduce the danger of flooding the tunnel due to pipe failure. The advantage of this high elevation reservoir will be that no pumping and energy expenditure is needed.

The disturbance area associated with the Raspberry Creek reservoir is estimated to be approximately 180 acres. Reclamation of this site would be limited to the dismantling and removal of water supply pipelines and associated facilities connecting the reservoir and the mill site/power plant, and the regrading and reseeding of disturbed areas.

Upper Hill Creek Reservoir

The annual storable runoff from upper Hill Creek may not be sufficient for use as the primary source of water supply for the ore processing and power plant facilities. The location of this reservoir is shown in Figure III-14.

Based on the available drainage area which can be impounded (2.9 square miles) and an estimated average annual runoff of 11 cfs per square mile, the mean annual discharge and the seven day, ten year low flow of the point of impoundment on Hill Creek are estimated to be 32 cfs and less than 5 cfs, respectively. Accordingly, the upper Hill Creek dam alternative can only be considered viable as a supplemental source of water supply. A pipeline from Upper Hill Creek must traverse dangerous landslide and avalanche zones and will impact mining operations. Other advantages and disadvantages of the Hill Creek reservoir are similar to those described previously for the Raspberry Creek reservoir. The disturbance area associated with the Hill Creek reservoir is estimated to be approximately 100 acres.

Reclamation of this site would be to dismantle and remove water supply pipelines and associated facilities connecting the reservoir and the mill site/power plant, and regrading and reseeding of these areas.

North Meadow Reservoir

The annual storable runoff tributary to this site may not be sufficient to serve as the primary source for the Quartz Hill water supply. The location of this reservoir is shown in Figure III-14. Based on the available drainage area tributary to the reservoir (5.7 sq. mi) and an estimated average annual of 11 cfs per square mile, the mean annual average discharge is estimated to be 63 cfs. Advantages and disadvantages of high altitude reservoirs such as this have been discussed previously in this section. The North Meadow site will require two dams to form the reservoir. Reclamation will be similar to that described for the Upper Hill Creek Reservoir.

Upper Lakes Reservoir

The Upper Lakes are located on the high ground on the west side of Wilson Arm opposite the proposed marine terminal as shown on Figure III-14. The major advantages of this source are the lakes' natural storage which would reduce reservoir costs, and that no minimum flow would need to be considered for fisheries protection since the outlet stream is too steep for spawning. Also, minimal pumping and energy expenditures are required.

The watershed drainage area is about 3.2 sq. mi. which limits it to a supplementary source. The major disadvantage is in its remote location and the spread of facilities to a new area west of the Wilson Arm.

Due to its remote location a connecting road and powerline to the east side of Wilson Arm are considered uneconomical. A wharf would be provided for water access, and then a steep road to the reservoir. The pipeline would cross Wilson Arm buried in a trench in the bottom sediments.

Other Small Sources

The use of several small sources for water supply rather than the larger Tunnel Creek reservoir has been evaluated. Since the runoff varies significantly during the year, particularly in these smaller basins, a storage reservoir and withdrawals from a supplemental source would still be required to meet plant water demands during low flow periods. Development of water supplies in these smaller basins would require access roads to points of diversion and along conveyance routes, carryover storage at the sources or at the plant site, conveyance facilities including pipelines and/or tunnels, and possibly pumping plants and power lines to each source. Development of small sources would be very expensive, be substantially less reliable (i.e., subject to natural hazard and greater natural flow variation), have potentially significant environmental impacts, and would not eliminate the need for development of the Tunnel Creek and Wilson River systems.

Desalinization

Processed seawater (desalinized to remove the dissolved salts) was considered as an alternate primary source of process water. This option would require construction and operation of an intake structure in either Boca de Quadra or Wilson Arm and construction and operation of a desalinization plant for processing the salt water.

Desalinization of seawater is extremely costly and energy intensive. Because of the added energy requirements, additional generation capacity would be required with attendant increases in fuel consumption, water use, and air emissions. Therefore, desalinization was not considered a viable alternative source of water supply.

Seawater

Raw seawater has been considered as a possible alternate source for the concentrator primary water supply. However, bench scale tests indicate that the high concentrations of dissolved salts in seawater interfere in the efficient recovery of mineral from the ore, resulting in a loss of 2 to 4 percent in molybdenum recovery. This could result in an annual revenue loss of $8 million to $20 million depending upon the prevailing molybdenum market. No operation of this magnitude in the world uses saltwater for flotation, therefore technical experience is limited and unreliable and risks are very high. Thus, this alternative was not considered further in this EIS.

Dewatering of Tailings

Dewatering of the tailings to reduce water demand and repulping with seawater could be accomplished by further treatment of the thickener underflows. It is estimated that by dewatering of tailings, an additional 30-35 percent of water could be recovered beyond the approximate 50 percent recovered by the thickeners. There are unresolved engineering factors as to the feasibility of doing this however, particularly in regard to the dewatering of slimes (very fine particles) in the tailings. There is no similar operation in the world of comparable size that could provide operating experience for design. Capital costs for the dewatering plant may range from $30 million to $100 million depending on the type of equipment and number of processing steps required. Operating costs would also increase significantly. Consequently, this alternative for decreasing water demands was not considered further in the EIS.

Blossom River Well Field

Geologic and geophysical testwork has indicated that the Blossom River aquifer can not provide the water needed for plant demands. The substrata are not suitable for providing water yield sufficient for reliable well withdrawal.

Wilson Tributary Reservoir

This alternative provides for a storage reservoir on a major but unnamed tributary to the Wilson River located a short distance upstream of the proposed wellfield as shown on Figure III-14. The major advantage of this source is the size of the watershed drainage area, about 15 sq. mi. The configuration of the valley with its low gradients lends itself to greater reservoir capacity with smaller dams. Disadvantages to the site are its remoteness from the concentrator, pumping costs due to its low elevation and the need for bridges across the Wilson River and possibly the Blossom River. In addition this alternative will spread the project facilities to a new area west of the Wilson River and to another spawning stream. For these reasons this alternative was eliminated from further consideration in the EIS.

Tunnel Creek as Sole Source

If Tunnel Creek is used as a sole water supply source, a larger reservoir would be required than for alternatives having a supplemental source. The dam would be 175 feet high and would require 3,350,000 cubic yards of fill material. The full reservoir would occupy 136 acres and would have a capacity of 8,940 acre feet. These dimensions assume a five cfs minimum flow requirement. If no minimum flow is required, the dam could be about five feet lower and the reservoir seven acres smaller. If a higher minimum instream flow is required, then the dam and reservoir would necessarily be larger.

5. Other Ancillary Facilities

Alternative options for most ancillary facilities have been discussed within the description of the major project components and will not be repeated here. Two facilities not discussed elsewhere include the following:

Log Transfer Facility

A log transfer facility is not part of the proposed project, but may be added later and permitted separately. The facility would be located at the Wilson Arm floating camp. To achieve a non-violent transfer of cut timber from trucks to the waters of Wilson Arm, the log bundles would be skidded down a slide of log cribbing to anchored skid logs. The log bundles would then be floated off the skid logs at high tide or pushed into the water for transfer to the stiff-leg boom for storage. The log transfer facility would be located immediately up-fjord of the construction barge berth.

Airport Sites

Potential airport sites on the west side of the Wilson River near its mouth and southeast of the Bakewell townsite were evaluated. Both sites have hazardous terrain that obstructs the flight path on approach and departure paths. Because of these hazards, the difficult terrain for airport construction, and the availability of alternative transportation modes, an airport has been eliminated from detailed consideration.

I. COMPARISON OF COSTS OF ALTERNATIVES

1. Alternative Project Concepts

Comparative costs for the proposed project and the range of alternatives described in this chapter have been prepared by U.S. Borax. These costs are estimates of capital costs for the first 20 years of mine operation only. All costs presented are in second quarter of 1984 dollars. Table III-4 presents the costs for the alternative concepts and the major components.

TABLE III-4

CAPITAL COSTS FOR ALTERNATIVE PROJECT CONCEPTS

Alternative Concepts (All Costs in Millions of Dollars)1/

Facility	Plant Site: Tailings:	Tunnel Wilson	Tunnel BOCA(A)	Tunnel BOCA(B)	Beaver BOCA Inner	Beaver Wilson	Beaver Land	North Meadow BOCA Inner	North Meadow Land
Mine		190	190	190	190	190	190	190	--
Ore Transport		60	60	60	17	17	17	34	--
Conc/Ancillaries		259	259	259	285	285	286	288	--
Power Supply2/		83	83	83	84	84	87	87	--
Water Supply		21	21	21	41	41	23	41	--
Tailings Disposal		9	42	68	44	16	1,844	42	--
Subtotal		622	655	681	661	633	2,447	682	--
Contingency		57	57	57	99	95	367	102	--
TOTAL QUARTZ HILL CAPITAL COSTS4/		679	712	738	760	728	2,8143/	784	(5)

1/ Includes only initial Quartz Hill 20 year estimated costs in second quarter 1984 dollars, and not replacement equipment costs.
2/ Onsite power plant.
3/ Land tailings figure developed for EPA was increased by 1 percent to change it from first Q 1984$ to 2nd Q 1984$.
4/ Includes commute option.
5/ Total capital costs not developed. Extra costs are required beyond that needed for the Beaver plant site/land tailings disposal alternative. Therefore, the total cost would be greater than $2,814 million.

BOCA (A) - Inner Basin
BOCA (B) - Middle Basin, at sill

Source: U.S. Borax 1984f. U.S. Borax 1985h. Envirosphere 1987.

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In addition to the overall concept alternatives, a range of component alternatives have been identified and described earlier in this chapter. The following sections provide the comparative costs for these alternatives.

2. Concentrator/Ancillaries

With the North Meadow mill site the mine access road would be constructed from tidewater up tne Keta River and then up Hill Creek to the mill. The cost of a two lane access road to the mill site is expected to be $37.3 million (1984 dollars) for a route with wooden snow sheds in avalanche areas. Due to avalanche risks in 7 areas along the route, large tunnels could be constructed to bypass these avalanche paths, these tunnels would add approximately $11 million to the cost of the road. After the completion of the Keta access road, the Blossom River route would be reclaimed. Reclamation of this road, including excavating and removing culverts to allow for open ditch drainage, removing bridges, removing other facilities, including the wharf, and seeding the road would cost approximately $648,000.

3. Tailings Disposal

Alternative ~~tunnel~~ alignments ~~have~~ been identified for the marine disposal alternatives to Boca de Quadra. For the Tunnel Creek mill site with tailings disposal to the middle basin of Boca de Quadra throughout the life of the mine, a tunnel could be constructed directly to the middle basin. The cost of such a tunnel is estimated to be $68.0 million. The tunnel to the inner basin would cost approximately $42.0 million. An extension to the middle basin via a pipeline generally following the shoreline of Boca de Quadra would cost an estimated $9.4 million. As shown in Figure III-2, an alternative alignment for the tailings tunnel from Beaver Creek has also been identified, which would result in a portal location below the Keta River estuary, rather than just above the estuary. The realigned tunnel from the Beaver Creek portal to the discharge location at Boca de Quadra would cost approximately $57 million. By comparison, the alignment from Beaver Creek to the near-estuary portal would cost approximately $34 million for the tunnel and $10 million for the surface pipeline to the inner basin discharge location, a total estimated cost of $44 million.

4. Housing

The proposed project incorporates the commute option with the employees being housed at facilities at the mine and mill during their on-duty period and commuting to Ketchikan during their days off. The capital cost of this option is estimated to be $9.0 million.

Development of a full service townsite in the vicinity of the project is an alternative to the commute option. Development of a townsite at Bakewell is estimated to cost $134 million. The capital cost of a Wilson I townsite is estimated to be $112 million. No capital costs have been developed for the Wilson IIa or Keta townsite alternatives. Capital cost estimates are for U.S. Borax costs.

5. Water Supply

The proposed project includes using Tunnel Creek as the primary water supply source with withdrawals from intake facilities on the Blossom River as a supplemental source. The feasibility of various scenarios or project water supply arrangements were examined in detail in a report by Envirosphere Co. (1987). Depending on the instream flow agreements and the size of dam on Tunnel Creek, this report estimated the capital cost plus the first 20 years' operating cost of using Tunnel Creek and a supplemental source from the Blossom River could range from $14.7 million to $50.4 million. The capital cost of the 52-foot high dam and associated facilities was estimated at $21 million.

If the mill is located at the Beaver Creek site or the North Meadow site, other combinations of water supply sources would be required. Estimated capital costs for a water supply for each different mill site were compared in Table III-4.

APPENDIX B

SIGNIFICANT ISSUES FOR THE EIS

QUARTZ HILL EIS

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
SURFACE HYDROLOGY				
The mine and its attendant facilities will significantly affect the surface water resources in the vicinity of the site	1. Potential for increased erosion and flow redistribution from changes in runoff due to:		Examine flow data and watershed characteristics, then estimate changes in runoff volumes and rates in order to determine post-project runoff patterns.	Change in surface flows.
	a. Clearing of vegetation for:			
	- marine terminal area	L		
	- road expansion & new road	L		
	- construction	H		
	- mine sites	H		
	- camp/townsites	H		
	b. Construction of project facilities (i.e., power plant concentrator, camp, etc.)	H		
	2. Potential for flow redistribution from changes in runoff due to:		Examine flow data and watershed characteristics, then estimate changes in runoff volumes and rates in order to determine post-project runoff patterns.	Change in surface flows.
	a. snow removal and disposal areas	L		
	b. waste rock disposal areas	L		
	c. topsoil/overburden piles	L		
	d. lean ore stockpiles	L		
	e. all impermeable surfaces (to be facility and resource specific)	L		
	f. mine development and dewatering	H		
	3. Changes in stream flow patterns due to project water requirements, to include wells, reservoirs, and diversions as appropriate.	H	Examine flow data, watershed characteristics, and project water requirements in order to estimate changes in surface water flows.	Change in surface flows.

1/ The significance or importance of an issue is listed here as the most conservative (i.e., highest) raised by one or more members of the interdisciplinary team (IDT). Judgements concerning significance did not consider the possibility for mitigating the potential impact or issue. H = high, M = moderate, L = low.

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
SURFACE HYDROLOGY (Continued)				
	4. Complete alteration of hydrologic characteristics due to on-land tailings disposal.	H	Examine flow data, watershed characteristics, and dam design in order to determine how the hydrology of the disposal area will change throughout the life of the project.	Change in surface flows.
	5. Potential for flooding and extreme erosion due to on-land tailings disposal dam failure.	H	Examine dam design, tailings characteristics, and watershed characteristics in order to predict hydrologic impacts.	Changes in surface flows.

QUARTZ HILL EIS

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
GROUNDWATER HYDROLOGY				
The mine and its attendant facilities will significantly affect the groundwater resources in the vicinity of the site	1. Potential for groundwater flow redistribution due to changes in surface hydrology	H	See Surface Hydrology flow rates.	Change in groundwater tables and
	2. Potential for lowering the groundwater table and subsequently altering the associated surface water flows due to:		Examine groundwater flow data and watershed characteristics, then estimate changes in groundwater volumes and flow rates in order to determine post-project groundwater tables and flow patterns.	Change in groundwater tables and flow rates.
	a. roadway cuts intercepting groundwater flows	M		
	b. installation of wells in uper river basins to meet project water requirements	H		
	c. dewatering of the aquifer in the mine pit area	H		
	d. disturbance of muskeg depositsand other saturated soils during construction	M		
	3. Complete alteration of groundwater characteristics due to on-land tailings disposal.	H	Examine groundwater flow data, watershed characteristics, and dam design then estimate changes in groundwater volumes and flow rates in order to determine post-project groundwater tables and flow patterns.	Change in groundwater tables and flow rates.

QUARTZ HILL EIS

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
WATER QUALITY				
The mine and its attendant facilities will significantly affect the surface and groundwater quality in the vicinity of the site	1. Changes in receiving stream* quality due to rainall runoff from:		Incorporate estimated changes in surface hydrology with soil type and erosion data in order to estimate changes in sediment loading and other water quality parameters.	Mass per unit volume for regulated and other key parameters; selected key physical parameters.
	a. marine terminal construction	H		
	b. road(s) construction	L		
	c. facilities construction	H		
	d. mine area surface development	H		
	e. townsite development	H		
	2. Changes in receiving stream quality due to sanitary waste discharges from:		Estimate waste discharge flow for population levels, then from proposed treatment plant data determine effluent quality and the subsequent receiving water quality using surface hydrology data.	NPDES requirements for sanitary treatment facilities.
	a. camps	H		
	b. townsite	M		
	c. recreation areas	M		
	3. Changes in receiving stream and groundwater quality due to rainfall runoff and seepage from:		Using leaching data, surface/groundwater hydrology data, stockpile volumes and areas, and proposed treatment systems, estimate the runoff quantity and quality.	Mass per unit volume for regulated and other key parameters; selected key physical parameters.
	a. topsoil/overburden piles	M		
	b. waste rock disposal areas	H		
	c. lean ore stockpiles	H		
	4. Changes in receiving stream quality due to surface/groundwater flow alterations (e.g, increase groundwater recharge due to reservoir) to be facility and resource specific	H	Incorporating the facility description with surface/groundwater hydrology data, determine the changes in surface/groundwater flow patterns and subsequent changes to water quality	Mass per unit volume for regulated and other key parameters; selected key physical parameters

* "Receiving Stream" is defined to include wetland areas as appropriate.

QUARTZ HILL EIS

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
WATER QUALITY (Continued)				
	5. Changes in receiving stream quality due to:		Using existing water quality data, facility descriptions and surface/ground-water hydrology data, determine the subsequent changes in receiving water quality.	Mass per unit volume for regulated and other key parameters; selected key physical parameters.
	a. mine development/dewatering (if appropriate)	H		
	b. developed impermeable area runoff	H		
	c. road deicing	H		
	d. reagent/fuel spills	H		
	e. tailings pipeline leakage and/or failure	H		
	f. snow removal/stockpiling	H		
	g. wash down waters	H		
	6. Changes in receiving stream and groundwater quality due to solid waste and sludge disposal.		Using facility descriptions, including treatment methodology and associated chemical additives, determine amounts and characteristics of sludges and solid waste; determine and/or evaluate disposal methods, then with surface/groundwater hydrology data determine changes in water quality.	Mass per unit volume for regulated and other key parameters; selected key physical parameters.
	7. Changes in receiving stream and groundwater quality due to on-land tailings disposal.	H	Incorporating dam design data, surface/groundwater hydrology, and tailings composition and characteristics, determine changes to surface/groundwater quality.	Mass per unit volume for regulated and other key parameters; selected key physical parameters.

TABLE 2 (con't)
QUARTZ HILL EIS

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
CHEMICAL OCEANOGRAPHY				
The mine, its potential attendant facilities, and tailings disposal will affect the water quality of Wilson Arm and Boca de Quadra	1. Changes in marine water quality due to alteration of freshwater quality (to be resource specific for both construction and operation phases).	H	Following estimation of freshwater resource water quality effects, estimates of marine water quality changes will be developed.	Mass per unit volume of regulated and other key parameters; selected key physical parameters.
	2. Changes in marine water quality and sediment composition due to construction of: a. marine terminal b. roads c. townsite	H	Hydrologic and geology/soils data, and sediment and erosion control methods will be reviewed. Estimates of loadings will be developed.	Mass per unit volume of regulated and other key parameters; selected key physical parameters.
	3. Changes in marine water quality due to process water and tailings discharge.	H	Review process water and mass balances. Determine effluent flows and concentrations. Review diffuser models. Determine spatial requirements for various dilutions.	Mass per unit volume of regulated and other key parameters and dilution zones.
	4. Changes in marine water quality and sediment composition due to tailings . disposal	H	Review chemical inputs, evaluate seawater transport and mixing rates. Evaluate chemical removal rates. Estimate chemical concentrations in water column and sediments.	Mass per unit volume of regulated and other key parameters; selected key physical parameters.
	5. Changes in marine water quality and sediment composition due to: a. marine terminal operation (runoff spills) b. shipping traffic (spills, ballast) c. road runoff d. small boat harbor e. sanitary waste discharges	 H H H H H	Review facility plans and design incorporated mitigation measures, estimate mass inputs. Estimate water quality changes.	Mass per unit volume of regulated and other key parameters; selected key physical parameters.

QUARTZ HILL EIS

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
PHYSICAL OCEANOGRAPHY				
The development including marine tailings disposals will alter the physical characteristics of Wilson Arm and/or Boca de Quadra	1. Alteration in the circulation pattern of the fjord as the volume, bathymetry, and ratio of tidal prism to the volume of resident water changes; changes in temperature and stratification; changes in sedimentation processes and patterns.	H	Evaluate diffusion and circulation mathematical models. Estimate changes to circulation, bathymetry, stratification, and sedimentation processes.	Changes in bathymetry and circulation as related to chemical and physical oceanography and aquatic resources.
	2. Changes in circulation patterns and siltation from construction and operation of marine terminal and small boat harbor.	H	Review existing circulation data, and facility design. Estimate changes to circulation	Changes in bathymetry and circulation as related to chemical and physical oceanography and aquatic resources

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QUARTZ HILL EIS

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
METEOROLOGY/AIR QUALITY				
The mine and its attendant facilities will affect the area's microclimate	1. Additional heat from: a. cooling systems b. new townsites	L	Quantify heat emissions, use conservative diffusion estimates.	Offsite impacts greater than 1°C annual average.
	2. Additional moisture from cooling systems causing fogging on highways and offsite.	M	Quantify cooling system emissions, use annual average and worst case diffusion estimates as available.	One hour per year of plume fogging on highways or at ground level offsite.
	3. Additional moisture from cooling system causing ice formation on roads, buildings, other structures.	M	Estimate frequency of ice formation based on cooling system design parameters, meteorological conditions and plume diffusion model.	One hour per year of ice formation on highways or on potential structures offsite.
The mine and its attendant facilities will affect the area's air quality characteristics	1. Ambient air quality standards may be exceeded due to: a. power plant b. concentrator c. townsite power plant	H	Using emissions estimates and available atmospheric diffusion modeling, estimates of ambient air quality will be made.	Any predicted violation of ambient air quality standards or the Prevention of Significant Deterioration Increments.
	2. Air quality maintained consistent with emissions standards.	H	Determine power plant compliance with New Source Performance Standards. Determine power plant compliance with PSD program Best Available Control Technology requirements.	Compliance with New Source Performance Standards. Compliance with Best Available Technology requirements.
	3. Ambient air quality standards may be exceeded due to fugitive and secondary emissions.	H	Estimate emissions from fugitive and secondary sources, based on design and technical literature. Emissions from mine operation, stockpiles, trucks, barges, construction and slash burning will be evaluated. Estimate potential levels of mitigation.	Fugitive particulate emissions less than 25 tons per year.

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SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
METEOROLOGY/AIR QUALITY (Continued)				
Emissions from the mine and its attendent facilities may affect atmospheric visibility	1. A visible plume may be detected offsite.	H	Estimate total particulate, sulfur dioxide, and nitrogen oxides emissions. Use atmospheric diffusion models and standard calculations of meteorological range.	Visual range less than 25 miles.
Emissions from the mine and its attendant facilities may cause odors	1. Odors may be detected	M	Similar facilities will be described and impacts from those facilities will be used to characterize impacts from the Quartz Hill facilities.	Offensive odors which may be detectible at the townsite or camp.
Emissions from the mine and its attendant facilities may affect	1. Power plants and dust may impact vegetation	M	Technical literature, describing generic impacts from pollutants will be used to characterize impacts.	

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
GEOLOGY, SOILS, AND AVALANCHES				
Stability of project features: a. mine slopes b. roads c. tunnel alignments d. tailings dam e. stockpiles (waste rock, lean ore, topsoil)	Effects of landslides and consequences of structural failures.	H	Review geologic data, seismic conditions, and engineering plans. Determine stability and/or mitigation.	
Adequacy of proposed erosion and sedimentation control measures	Effects of erosion and sediment loading on surface watercourses.	H	Review soils data, determine erodibility, review erosion and sedimentation control measures. Determine adequacy and/or mitigation.	
Project personnel and facilities could be exposed to avalanches	Effects of avalanches on personnel safety and facilities.	H	Review avalanche information and engineering plans. Determine potential and mitigation measures.	

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
NOISE				
The mine and its attendant facilities will create noise levels incompatible with the townsite and with wilderness values	1. Increased noise levels due to a. mine operation b. power plant, concentrator, and other support facilities c. road traffic d. air traffic e. avalanche control f. townsite	M	Enumerate noise generating processes, estimate area noise levels.	Noise level criteria.

QUARTZ HILL EIS

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
AQUATIC RESOURCES				
Marine Wharf or small boat basin	1. Possible migration delay, disorientation, allowing increased predation of shoreline migrating juvenile salmon.	H	Using data on smolt timing and abundance during emigration period, food habits of potential salmon smolt predators, and literature on food consumption rates, estimate predation rates.	Predator consumption rates of juvenile salmon (i.e., No. per day).
	2. Oil or chemical spill.	H	Define potential toxicants and estimated concentrations, based on worst case (i.e., entire load) estimates of volumes that could be spilled. Estimate effects on habitats, fish, invertebrates. Consider toxicity and potential accumulation in food chains.	EPA (1980) water quality criteria and literature pertaining to vulnerability of key biological resources.
	3. Habitat alteration.	M	Estimate acres of benthic habitat that may be altered. Attempt to rank importance of habitat in terms of economically or recreationally important species and such parameters as food organisms.	Acres of habitat.
	4. Siltation of aquatic habitat from construction and operation.	H	Using estimates of sediment deposition and circulation patterns, determine acres of benthic habitat wherein extensive mortality would be anticipated for those benthic organisms used as important sources of food for juvenile salmon.	Acres of habitat.

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
AQUATIC RESOURCES (Continued)				
Staging area	5. Noise impacts from blasting during construction.	M	Estimate anticipated magnitude of blast pressure waves in water and compare to fish sensitivity with reference to timing of occurrence in the area.	Sensitivity of key fish species to pressure waves (percent mortality).
	6. Chronic introduction of chemicals via runoff to estuary.	H	Define potential toxicants, estimate loading rates, estimate concentrations in situ (need flushing data for fjord), and estimate effects on fish and representative benthic invertebrates using general literature. Also consider potential for accumulation in food chains using literature and structure-activity relationships.	Toxicant concentrations and tissue residues versus EPA (1980) water quality criteria, if data available, or literature.
	7. Acute oil or toxic substance spill	H	Describe briefly the relative acute toxicity of the fuel oils or chemicals used to aquatic habitats, fish, and intertidal benthic invertebrates, based on worst case (i.e., entire load) estimates of volumes that could be spilled.	Vulnerability of aquatic habitats to oiling with reference to key biological resources.
Marine operating and shipping traffic	8. Conflict with fixed commercial fishing gear	L	Delineate shipping versus fishing areas. Estimate degree of overlap and evaluate feasibility of ranking according to value of fisheries.	Area of potential overlap (acres).
	9. Chronic introduction of oil to waters and biota	H	Estimate maximum volumes of oil that could be spilled per year and discuss toxicity to fish and intertidal benthos. Contrast to rates oil would be expected to disappear via self-cleansing, biodegradation, etc.	Map depicting vulnerability of aquatic habitats to oiling with reference to important biological resources.

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SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
AQUATIC RESOURCES (Continued)				
Bridges and culverts on overland access road (dock to mine)	10. Potential blockage of anadromous fish, rendering upstream habitat unvailable.	H	Identify streams containing anadromous salmonids and where fish spawn and rear Compare with alternative road locations.	Streams containing significant runs of anadromous salmonids and miles of streams affected (or acres of habitat).
Tideflat road fill (width 46 ft x 1 mi)	11. Elimination of aquatic habitat thereby reducing production of estuary.	H	Area of aquatic habitat filled and area probably used by salmonid fry for rearing.	Area of habitat disturbed (acres).
	12. Siltation of nearby areas.	H	Using data on amount of sediment exported to aquatic environment and estimates of where it will settle, estimate areal extent to which salmonid spawning and benthic invertebrate production will be harmed.	Spawning areas and benthic habitat harmed (acres).
	13. Possible alteration of current and tidal patterns in estuary.	L	On map contrast main river and tidal channels with location of fill. Estimate flow in channel(s) impacted.	Areal extent (acres) of river/tidal channel habitat where flow has been changed due to diversion.
Road and utility corridor	14. Siltation of nearby estuary and of streams crossed.	H	Using estimates of sediment deposition amounts and sites, estimate extent to which anadromous salmonid spawning and rearing habitat would be disturbed by roads with different surfaces.	Area of habitat disturbed (acres) based upon Section 7C of Alaska water quality standards and literature.
	15. Oil or chemical spill from storage tank or pipeline rupture; chronic pollution from road runoff (e.g., deicing agents).	H	Using data on location and volume of storage facilities, data on toxicity of the substances, and probability of spillage, predict which streams and waterbodies and biota would be affected and extent of effect.	Areal extent (acres) of waterbodies whose aquatic biota would be affected based upon Section 10C of Alaska water quality standards and literature.

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SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
AQUATIC RESOURCES (Continued)				
Mining and Processing				
Mine and plant site	16. Loss of aquatic habitat of plant site (limited).	M	Determine and map size and length of streams destroyed and disturbed.	Length and size of streams altered (mi) and acres of stream habitat.
Water reservoir	17. Alter 125 acres of aquatic wetland (meadow), remove from use by aquatic biota.	H	Determine and map size of wetland destroyed and disturbed.	Area of habitat altered (acres).
Water withdrawal	18. Possible reductions in flow to feeder streams could reduce flows in streams inhabitated by anadromous salmonids.	H	Identify monthly water requirements of mine and mill and streams from which water will be taken; estimate minimum streamflows needed by anadromous salmonids for (as applicable) migration, spawning, and rearing; and compare supplies with fish requirements.	Water supply (cfs) and minimum streamflows (cfs) required by fish or regulation (e.g., DNR).
Surface erosion	19. Increased siltation to drainage streams.	H	Using estimates of amounts of sediments and locations where siltation is expected, determine degree to which spawning and benthic invertebrate production may be adversely affected.	Acres of stream habitat used by anadromous salmonids that may be silted significantly based upon Section 7C of Alaska water quality standards and literature.
Oil fired generators (fuel spills)	20. Spill into stream, impacts to aquatic biota downstream into estuary.	H	Identify type of chemicals and volumes that could be spilled. Estimate range of toxicity to fish and freshwater invertebrates and compare to expected concentrations in streams given chemical's solubility and duration of expected exposure. Estimate expected toxicity to fish and invertebrates as percentage mortality or effect.	Acres of habitat where acute mortality of (1) fish and (2) invertebrates could be expected, based upon Section 10C of Alaska water quality standards and literature.

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SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
AQUATIC RESOURCES (Continued)				
Overburden, waste rock, lean ore disposal				
Leachate from stockpiles	21. Degraded water quality may impact aquatic biota in streams.	H	Identify types of chemicals having a significant aquatic toxicity potential and estimate concentrations expected *in situ* and duration of exposure. Compare sensitivities of fish and invertebrates to chemical concentrations and assess bioacumulation/biomagnification potential.	Miles of stream and acres of stream habitat where toxicity and biomagnification to fish and invertebrates could be expected based upon EPA (1980) water quality criteria, Section 8C of Alaska water quality standards, and literature.
Waste rock disposal	22. Indirect impacts on aquatic resources.	H	Address in same manner as potential aquatic impact 21.	
Sediment (settling) pond	23. Degraded water quality in pond effluent may impact aquatic biota in streams.	M	Address in same manner as potential aquatic impacts 19 and 21.	
Reduced flows and added discharge of leachate to streams	24. Reduced aquatic productivity for anadromous fish.	H	Address in same manner as potential aquatic impacts 19 and 21.	
Tailings Disposal - Land Disposal				
Disposal site	25. Loss of stream fish habitat.	H	For candidate streams, determine reaches of streams used for spawning and rearing of anadromous salmonids and compare to location of proposed facility.	Miles of stream and acres of stream habitat used by anadromous fish that would be affected.
Access roads	26. Impacts to aquatic life could be multiplied because of two major road systems could be constructed.	H	Address in same manner as potential aquatic impacts 10, 14, and 15.	

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
AQUATIC RESOURCES (Continued)				
	27. Blockage of anadromous fish.	H	Evaluate in same manner as potential impact 25.	
	28. Siltation reduces aquatic habitat.	H	Evaluate in same manner as potential impact 19.	
	29. Acute oil spill.	H	Evaluate in same manner as potential impact 15.	
Tailings dams and discharge	30. Alteration of groundwater hydrology may impact aquatic productivity of watershed.	H	Evaluate extent to which changes in groundwater hydrology affect flows in streams used by anadromous salmonids. Contrast to minimum and maximum flow regimens (as applicable) suitable for fish uses (e.g., spawning).	Ambient and altered streamflows (cfs) and flow requirements of anadromous salmonids (cfs), miles of stream in which anadromous salmonids could be affected.
	31. Surface hydrology change causing loss or limitation of spawning by salmon in lower creeks.	H	Evaluate in same manner as potential impacts 18, 19, and 21.	
	32. Dam failure - impact aquatic biota of streams and estuary.		Assume all biological resources downstream would be destroyed. Calculate miles of stream destroyed and miles used by anadromous salmonids. Recovery rate will not be considered.	Miles of stream or acres of habitat.

TABLE 2 (con't)
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SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
AQUATIC RESOURCES (Continued)				
Alternate - Marine Disposal				
Tailings slurry discharge	33. Below a certain depth, the continuous deposition of tailings may bury benthos and eliminate use by marine biota. At shallower depths, there may be losses of some marine biota and reduced primary and secondary productivity. Possible rupture of slurry pipeline will also be considered.	H	To gauge the effects of sedimentation, estimate depth of sediment expected in the following zones: intertidal, sublittoral to a depth of 100 feet (ft), and subtidal greater than 100 ft depth. Estimate areal extent of sedimentation and contrast to depth range and areal extent of distributions of economically important benthic and epibenthic fish and invertebrates. These include crab (e.g., king crab) shrimp (e.g., spot shrimp), demersal fish (e.g., flatfish and cod), and molluscs (e.g., bay mussels). Also included are intertidal and sublittoral invertebrates that are important prey for chum and pink fry. Use literature to estimate sediment depths that sessile benthic infauna and mobile epifauna can tolerate. Assume that all habitat below depth of discharge will be uninhabitable. To assess biotic effects of suspended solids in water column, attempt to estimate suspended solids concentrations expected in the water column at the following depths: surface, mean low water to mean high water, euphotic zone, sublittoral to depth of 100 feet, and greater than 100 ft. Compare estimates to literature detailing effects of suspended sediment on filter-feeding invertebrates, on avoidance by fish, and on toxicity to fish and invertebrates. Estimate effect of suspended solids on depth of euphotic zone and on primary production.	Sedimentation effects: area (acres) of habitat loss for economically important fish and invertebrates (i.e., crab, shrimp, demersal fish). Suspended solids effects: percentages of fish and filter-feeding invertebrates avoiding or being killed by suspended solids and reduction in biomass (carbon) production in fjord due to any depressant effect on primary production.

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SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
AQUATIC RESOURCES (Continued)				
Alternate - Marine Disposal				
Toxicity of slurry	34. Toxicity of slurry to marine biota may reduce productivity	H	Estimate dilutions of slurry that will occur at the following depths: surface, depth range corresponding to mean low water to mean high water, euphotic zone, sublittoral to 100 ft, and greater than 100 ft. Based on expected concentrations of trace metals, milling reagents, and other chemicals introduced that have a significant aquatic toxicity, estimate concentrations that would occur at different depths. Based on the fjord's flushing rate at different depths and on chemical data indicating biodegradation, hydrolysis, etc. rates, judge the extent to which the chemicals would accumulate or be removed from the fjord. Contrast anticipated exposure concentrations and duration with acute and chronic toxicity data for fish. Consider bioaccumulation and biomagnification potential for fish and higher carnivores.	Areas (acres) and general depths within fjord possessing water quality that may be acutely or chronically toxic to fish and invertebrates and result in significant chemical residues in economically important fish. Based upon EPA (1980) water quality criteria, Alaska water quality standards, and literature.
Housing, Townsites, Campsites				
Aquatic resources	35. Degraded water quality of streams receiving sewage effluent or runoff from developed areas (e.g., roads) and impacts to aquatic life of changes in streamflow due to changes in runoff.	H	Water Quality: Using data on identity, concentrations of significant potential toxicants, and exposure times, estimate percentage of fish and invertebrates in streams and estuary that would be harmed or accumulate chemicals. Based on distribution of affected organisms, determine miles of stream and square miles of estuary that would be affected.	Miles of stream and area (acres) of estuary or fjord where significant effects on aquatic biota may be expected.

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
AQUATIC RESOURCES (Continued)				
Housing, Townsites, Campsites				
	Degraded water quality of streams receiving sewage effluent or runoff from developed areas (e.g., roads) and impacts to aquatic life of changes in streamflow due to changes in runoff.		Streamflow: Compare the expected streamflow regimens with minimum and maximum flow requirements of anadromous salmonids for migration, spawning, and rearing (as applicable) during the months when fish are in the stream(s). Identify the months and miles of stream where fish use would be affected.	Months and miles of streams where where effects on anadromous salmonids expected.
	36. Increased fishing pressure leading to reduced salmon escapement.	H	Based on per capita estimates of salmon fishing success and poaching rates, estimate annual harvest of salmon for streams where fishing allowed or proximate to townsite or roads. Compare to existing salmon run size ranges for streams.	Numbers of fish harvested or or poached without area or stream closures.

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SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
TERRESTRIAL RESOURCES				
Marine wharf or small boat basin	1. Disturbance to seasonal waterfowl, shorebird, eagle use.	H	Based upon seasonal bird use data, estimate distance birds will move away from facility and calculate areas where natural habitat of key species would be affected.	Reduction in numbers.
Staging area	2. Removal of 10-15 acres of forest and associated wildlife habitat.	H	Categorize amount (acres) of habitat lost according to vegetation assemblage and type of use by key wildlife species. Based on densities of key wildlife species believed to use the affected habitats, estimate numbers affected.	Reduction in numbers of key species.
	3. Blasting and noise influence wildlife and marine mammal movements.	H	Estimate anticipated magnitude of noise at various distances from source, and compare to wildlife sensitivity, and estimate distances key species will move away from noise.	Acres of habitat whose use by key wildlife species has been reduced.
	4. Acute oil spill impacts to waterfowl, shorebirds.	H	Describe susceptibility to oiling of key waterfowl and shorebirds in relation to types and volumes of oil that could be spilled. Based on numbers of birds using area and their habits, estimate numbers that could be harmed.	Numbers of key waterfowl and shorebirds harmed.

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ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
TERRESTRIAL RESOURCES (Continued)				
Overland Access Road				
Tideflat fill	5. Reduction in waterfowl habitat and harassment of wintering waterfowl.	H	Categorize amounts of waterfowl habitat lost and estimate loss to waterfowl.	Area (acres) of habitat alteration and numbers of key waterfowl species.
Road and utility corridor	6. Removal of 50 acres of forest and wildlife habitat.	H	Address in same manner as terrestrial impact 2.	
	7. Disturbance to wildlife from traffic along roadway and estuary (e.g., disruption of existing movement corridors and channeling of wildlife along the road).	H	Address is same manner as terrestrial impact 3.	
	8. Increased hunting pressure.	H	Based on per capita estimates of hunting success and poaching rates, estimate annual harvest of game species	Numbers harvested assuming no area closures.
	9. Road salting and snow removal effects on vegetation.	L	Describe the relative toxicity of road salt to vegetation in relation to the amount of salt applied, the frequency of application, and timing of application. If possible briefly differentiate sensitivities between major plant species and attempt to estimate the distance from the road and miles of roads affected. Map roads that will be salted. Also map roads that will be plowed in winter. Evaluate effects of snow drifts on phenology of roadside vegetation and any changes in the latter's character.	Miles of road affected by salting and snow removal and acres of vegetation adversely affected by salt.

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
TERRESTRIAL RESOURCES (Continued)				
Road and Utility Corridor (Continued)				
	10. Chronic oil and toxic substance, sediment runoff from roadway surfaces.	M	Using data on expected amount and toxicity of substances hauled, amout used as dust control, and probability of spillage, predict wildlife habitat impacts and effects on wildlife.	Acres of wildlife habitat affected
	11. Acute oil or toxic substance spill impacts to waterfowl, shorebirds.	H	Address in same manner as terrestrial impact 4.	
Mining and Processing				
Mine and plant site	12. Loss of 1000 acres of vegetation and wildlife habitat of moderate value.	H	Address in same manner as terrestrial impact 2.	
	13. Noise and activity will reduce wildlife density of adjacent areas; movements will be altered.	H	Address in same manner as terrestrial impact 3.	
Water reservoir	14. Loss of 125 acres of meadow (bear habitat).	H	Address in same manner as terrestrial impact 2.	
Water withdrawal, surface erosion oil fired generators (fuel spills)	15. Indirect impact on terrestrial resources.	H	Address in same manner as terrestrial impact 2. Refer to treatment of aquatic impacts 14, 16, and, 17, 18, and 18 in developing section.	

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SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
TERRESTRIAL RESOURCES (Continued)				
Overburden, waste rock, lean ore disposal				
Waste rock disposal	16. Loss of 580 acres of vegetation and wildlife habitat of moderate value.	H	Address in same manner as terrestrial impact 2.	
	17. Noise will alter big game movements.	L	Define normal migration routes and habitat usage of key wildlife species. Estimate their response to anticipated noise levels in area. Predict any changes in use or routes of movement. Map data.	Areal extent (acres) to which habitats altered. Extent to which length of routes between basins altered by noise or habitat change.
Leachate from stockpiles, sediment pond	18. Indirect impacts on terrestrial resources.	M	Identify type and concentrations of chemical constituents having significant wildlife toxicity in water. Contrast to toxic concentrations to wildlife.	Percentage effect on populations of key wildlife species.
Reduced flow and added leachate discharge to streams	19. Reduced use by waterfowl, shorebirds.	M	Address in same manner as terrestrial impacts 15 and 18.	
Tailings disposal - land disposal alternative				
Disposal site	20. Loss of 2300 acres of vegetation and wildlife habitat.	H	Address in same manner as terrestrial impact 2.	
	21. Noise and activity reduce wildlife use of adjacent areas.	M	Address in same manner as terrestrial impact 3.	

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
TERRESTRIAL RESOURCES (Continued)				
Tailings disposal - land disposal alternative				
	22. Big game movement pattern altered.	M	Address in same manner as terrestrial impact 17.	
	23. Reduced use of lower Tunnel and Aronitz creeks by eagles and bears feeding on salmon (because of effect of tailings effluent on fish).	H	Based on known or projected eagle and bear use of streams during salmon spawning period, estimate effects of reduced food supply during this period, assuming certain portions of the streams may support lesser numbers of fish.	Numbers of eagles and bears.
	24. Dam failure - impact wildlife use of downstream areas.	H	Assume all biological resources downstream would be destroyed. Calculate habitat destroyed, wildlife use lost.	Numbers of key wildlife species.
Marine Disposal Alternative				
Effects of slurry	25. Impacts on marine mammals and birds.	H	Impacts are expected to be primarily on food supplies of seals, waterfowl, and shorebirds. Therefore, define food habits and requirements of key species and compare to predicted availability of their prey as per the evaluation of aquatic impact 33. Effects on population sizes of key wildlife species from changes in prey availability will be qualitative; percentage reductions in prey habitat will be assumed to lead to corresponding reductions in predator use of area.	Numbers or percentages of key marine wildlife species.
Rupture of slurry pipeline	26. Impact all biological resources down slope.	H	Address in same manner as impact 24.	

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
TERRESTRIAL RESOURCES (Continued)				
Townsites, campsites				
Terrestrial resources	27. Loss of 250 acres of vegetation and wildlife habitat.	H	Address in same manner as terrestrial impact 2	
	28. Noise and activity may reduce wildlife use of adjacent areas and change big game movements.	M	Address in same manner as terrestrial impact 3	
	29. Increased hunting pressure on bears, goats, waterfowl and furbearers.	H	Address in same manner as terrestrial impact 8.	
	30. Refuse from human habitations may attract bears, necessitating or facilitating their destruction.	M	Estimate numbers of bears based on experience from other communities.	Estimated number of bears destroyed.

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
SOCIAL SCIENCES - Socioeconomics				
Potential boom or boom-bust effect in Ketchikan Gateway Borough due to project construction and possible deferral of townsite development until production reaches 60,000 tons per day; potential speculative in-migration of workers anticipating employment opportunities;	Shifts in economic base.	H	Analysis of industry sector output and employment shifts due to increased construction and mining activity.	Increased economic dependence on single local industry.
	Employment and unemployment.	H	Projections of employment, population, and and unemployment based on varying project development plans and without project development.	Average project-induced unemployment rate above 2 percent.
	Income	H	Projections of total and per capita personal income with and without the project.	Total project-induced income decline of 2 percent in one year.
	Population size, distribution, and composition.	H	Project population of Ketchikan, Borough, and new community based on alternative development scenarios and no project development.	Project-induced population increase of more than 2 percent per year.
	Housing	H	Project housing supply and demand in Ketchikan and new community based on alternative project development scenarios and no project development; evaluate project's effects on housing prices; determine ability of local housing industry to meet demand.	Housing shortage leading to project-induced price escalation in excess of 2 percent per year; housing surplus with vacancy rate exceeding 2 percent. Other signs of boom/bust potential.
	Increased demand for public facilities and services - utilities, transportation, education, medical services, police and fire protection, recreation, marine facilities.	H	Project demand for public facilities and and services under alternative project development scenarios and with no project development; need for expansion of port facilities personnel.	Need for major capital improvements and staff expansion - streets, utilities, school rooms, hospital beds, social and health workers, other services.
	Local fiscal effects	H	Project Ketchikan, Borough, and school district revenues and expenditures under alternative development scenarios and with no project development.	Borough or city government or school capital outlays exceeding revenues or bonding capability.

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ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
SOCIAL SCIENCES - Socioeconomics (Continued)				
	Increased land use requirements to support development.	H	Project land use requirements under alternative development scenarios with no project development.	Land use conversion requirements in excess of land availability.
	Increased planning and zoning, and enforcement requirements.	H	Determine need for additional city and Borough planning and enforcement based on land use and public facilities and services requirements and existing resources.	Need for program and staff expansion.
Potential adverse socio-cultural impacts on Ketchikan and Ketchikan Gateway Borough due to increase in local populations	Stress on community cohesion and cultural conflicts - lack of social assimilation, compatibility of lifestyles, congestion.	H	Assess social needs and characteristics of project-related population influx and existing population; identify potential conflicts; examine results from Amax mine.	Need for enhanced social services.
Project will produce new jobs in Ketchikan vicinity, but local workers might not fill positions	Continued high local unemployment rates; lack of project contribution to employment opportunities.	H	Project employment based on alternative assumptions concerning local hiring policies.	Lack of project contribution of 200 jobs to Ketchikan or SE Alaska workers.
	Higher population growth due to speculative in-migration of workers.	H	Project population based on alternative assumptions concerning local hiring practices including affirmative action and training programs.	Project-induced unemployment rate increase in excess of 2 percent.
Through possible adverse effects on local fisheries, project might adversely affect local commercial fishing industry	Reduced commercial and sports fishery harvest, income to commercial fishermen and industry.	H	Assess project's potential fisheries impacts, available from biological sciences discipline; relate to current commercial fishing harvest in project area.	Reduction of local fishery harvest and industry employment of 5 percent.
Project could affect tourism through development of pristine areas in National Monument; reducing or altering areas attractiveness to tourists	Changed numbers of tourists income to local tourist industry.	H	Assess current tourism uses of project vicinity, potential for decline in future use due to project development and financial effect on local tourist industry.	Reduction of tourism by 5 percent.

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ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
SOCIAL SCIENCES - Socioeconomics (Continued)				
Potential for project to reduce operations periodically due to cyclical demand for molybdenum	Periodic layoffs of employees, secondary impacts on local employment; increased demands on local social services and state unemployment outlays.	H	Assess stability of molybdenum market, long range trends, competitiveness of project in world market; estimate probability of temporary mine closure or reduced production; relationship to timber cycles.	Project-induced unemployment increase of 2 percent.
		H	Analyze workforce levels and dependent employment associated with project.	
		H	Estimate effects on housing, the general economy, local social services, and unemployment outlays associated with potential unemployment.	
Although project's economic life is estimated to be 70 years, it may have adverse impacts when closure finally occurs	Structural job losses in local job market; reduction of employment in local services industry Estimate effects on housing, the general economy, local social services, and unemployment outlays associated with potential unemployment.	H	Analyze workforce levels and dependent employment associated with project per year.	Project-induced unemployment rate increase in excess of 2 percent.
Potential problems exist with each alternative townsite location; there may not be a totally acceptable site	Living conditions of townsite residents may suffer in several areas: lack of adequate utilities, inadequate transportation system either within town, between town and mine, or between town and outside; lack of sunlight, air quality degradation, public safety.	H	Assess each alternative townsite with respect to provision of utilities, transortation systems, including ground, water, and air, days of sunlight, air quality, and public safety; recreation and entertainment opportunities; incentive for local business opportunities; housing layouts and design.	Inadequate water or electric power supply; inadequate access to townsite by water or air; difficult or lengthy commute to mine; air quality problem from project operation; lack of direct sunlight throughout year, presence of natural hazards to townsite residents.

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
SOCIAL SCIENCES - Socioeconomics (Continued)				
Residents of new town may not have self governing status; town may be managed by U.S. Borax and become "company" town	Residents would be subject to company policies both on and off job.	H	Analyze town ownership and government alternatives; assess ramifications to residents of each alternative; address potential for land ownership exchange.	Excessive regulation or regimentation of townsite residents.
Project is attractive to State of Alaska due to its positive effects on state employment and income and state government revenues; however, state expenditures associated with project development and operation may exceed revenues	Rise in statewide employment levels directly and indirectly attributable to project	H	Project mine construction and operation employment, local services employment in Borough.	Direct and indirect increase in statewide employment of 5 percent; stabilization of employment base in SE Alaska.
	Increased tax revenues to state	H	Project state tax revenues associated with mine development and operation and corporate income.	
	Increased state expenditures	H	Determine and cost out new state services directly attributable to project construction and operation.	Expenditures in excess of revenues.
Project is attractive at national level due to positive effects on international balance of payments and contribution to domestic production of strategic materials	Positive contribution to nation's international balance of payments	H	Project project's production of molybdenum, world demand and world prices, estimate domestic and international use of molybdenum and project's contribution to foreign shipments; project value of foreign shipments attributable to project's operation.	Contribution in excess of $15 million, or .1 percent of average international balance of payments deficit.
	Positive contribution to domestic strategic mineral production capability	H	Assess strategic importance of molybdenum in context of national and world economies; assess significance of project in terms of mineral's strategic importance and mine's production levels.	

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ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
SOCIAL SCIENCES (Continued)				
Power Resources				
Project's high power loads could stimulate development of a regional electric power grid, resulting in additional environmental impacts	New power generation facilities; transmission line construction; environmental impacts associated with power plant and transmission line construction.	H	Assess results of planning efforts conducted to date for developing a regional power grid in southeast Alaska; assess potential availability of power from sources outside project; assess effect of project on feasibility of regional power grid; assess general type of transmission grid and generally assess types of environmental impacts likely to occur.	Construction of power project or transmission line
Project could encourage development of regional hydropower potential, producing additional environmental impacts	New hydropower construction, transmission line construction, and resulting environmental impacts.	H	Review regional hydropower plans and potential; identify potential transmission corridors; assess general types of environmental impacts associated with potential hydroelectric development.	Construction of hydropower project or transmission facility.
Project could lead to construction of a natural gas pipeline across wilderness area	Land use change, wildlife habitat disruption, and aesthetic degradation.	H	Review plans and potential for pipeline construction; assess in general terms types of environmental impacts associated with pipeline construction.	Construction of gas pipeline.
Cultural Resources				
Project could adversely affect archaeological and historic sites during construction and operation	Disturbance of sites through construction and operation activities; visitor disturbance through increased access and use.	H	Assess results of surveys in project area; identify known sites and areas of high potential for possessing cultural sites; analyze significance of sites in accordance with provisions of National Historic Preservation Act.	Significance level is physical damage to any register-eligible site, or its integrity, with allowance for mitigation measures. For non-eligible sites, significant impact would be failure to protect or preserve representative sample.

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SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
SOCIAL SCIENCES (Continued)				
Land Use and Recreation				
The project will adversely affect land use objectives of the National Monument and adjacent wilderness area; land uses may be incompatible; influx of workers and families to project area may compromise Monument values	Heavy machinery and air and waterborne traffic	H	Estimate levels and characteristics of traffic and locations with respect to Monument and wilderness area; assess effects on users.	Diminished value of wilderness recreation experience to point of displacing users.
	Noise and emissions from construction and mining equipment	H	Estimate effect levels and impacts on Monument users.	
	Increased and sustained human presence in Monument	H	Estimate future human use of Monument by type and level; assess effects on Monument and wilderness values; assess increased hunting and fishing pressures; assess effects on existing subsistence uses of area.	Future use increase of 20% above trend (criterion dependent upon use distribution and apparent Monument capacity); diminishing of Monument and wilderness values; displacement of users from accustomed areas.
Population growth in Ketchikan and Borough will place increased and more dispersed pressures on Monument beyond those associated with the new townsite; this pressure may aggravate project's potential land use conflicts	Increased hunting and fishing in Monument	H	Assess increased recreation demand in Monument from increased population; Forest Service Recreation Information Management (RIM) System data will be used in estimating increased recreation demand.	Same as above.
Land use and access controls may be needed in order to preserve Monument values and conform to coastal zone plans	Central ownership of townsite in order to implement land use and access controls.	H	Analyze townsite ownership alternatives with respect to implementing land use and access controls.	
	Restrictions on access to or use of Monument.	H	Assess need for restricting access to Monument, particularly wilderness, to preserve existing values.	Need for restrictions would be significant.

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SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL[1/]	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
SOCIAL SCIENCES (Continued)				
Land Use and Recreation				
	Increased complexities and costs of installing utilities and communications systems.	H	Assess alternative routing of utility and communications systems with respect to National Monument and wilderness objectives.	
Aesthetics				
Project will detract from visual attractiveness of National Monument and Wilderness area	Construction of mining and transportation facilities adjacent to pristine areas; noise and emissions from construction and mining equipment; viewer sensitivity will be affected with introduction of townsite (e.g., increased viewing frequency).	H	Assess Forest Service visual resource management objectives for National Monument and wilderness area, project impacts on visual resources and analyze compatibility of project with management objectives; integrate with land use and recreation analyses.	Diminished value of recreation experience; project incompatible with visual resources management objectives.

QUARTZ HILL EIS

SIGNIFICANT ISSUES

ISSUE	TYPES OF POTENTIAL IMPACTS	SIGNIFICANCE LEVEL 1/	IMPACT ANALYSIS METHODS	IMPACT CRITERIA
MONUMENT AND WILDERNESS				
Project may induce changes (physical, biological, or social) which could adversely affect the National Monument or adjacent wilderness.	Smoke, dust, sediment, light, noise, odors, vegetative changes, etc.	H	Estimate amounts and effect on Monument and wilderness. Use results of analysis previously described in this Table to analyze the physical and biological effects.	Presence of impact factors.
The project will adversely affect land use objectives of the National Monument and adjacent wilderness area; land uses may be incompatible; influx of workers and families to project area may compromise Monument values.	Heavy machinery and air and waterborne traffic.	H	Estimate levels and characteristics of traffic and locations with respect to Monument and wilderness area; assess effects on users.	Diminished value of wilderness recreation experience to point of displacing users.
	Noise and emissions from construction and mining equipment.	H	Estimate effect levels and impacts on Monument users.	
	Increased and sustained human presence in Monument.	H	Estimate future human use of Monument by type and level; assess effects on Monument and wilderness values; Assess increased hunting and fishing pressures; assess effects on existing subsistence uses of area.	Future use increase of 20% above trend (criterion dependent upon use distribution and apparent Monument capacity); diminishing of Monument and wilderness values; displacement of users from accustomed areas.

APPENDIX C
METEOROLOGY, CLIMATOLOGY, & AIR QUALITY

APPENDIX C
METEOROLOGY, CLIMATOLOGY, AND AIR QUALITY

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1.0 INTRODUCTION

1.1 STUDY OBJECTIVES

This document describes the methods used by Envirosphere Company to calculate the air quality impacts of the U.S. Borax (USB) Quartz Hill molybdenum project near Ketchikan, Alaska. The Alaska Department of Environmental Conservation (ADEC) and EPA Region 10 in Seattle have requested that a detailed air quality analysis be included in the Final Environmental Impact Statement for the project. Those two agencies indicated that the simplified air quality analyses included in the 1983 Prevention of Significant Deterioration Permit Application and in the Draft EIS did not adequately predict the impacts of emissions from the mining operations and from the Tunnel Creek power plant.

In response to the agency comments, USB has directed Envirosphere to conduct rigorous air quality dispersion modeling for the project. The detailed modeling utilized the meteorological data that USB has been collecting at the site since 1980. EPA-recommended modeling techniques and preferred air quality computer models were used to calculate the annual average and short-term pollutant concentrations on a grid system around the mining operations and power plant.

In this document, the following items are provided:

- Applicable air quality regulations;
- A complete emission inventory, predicted emissions from all point sources, mobile sources, and fugitive dust;
- A compilation of the meteorological data used for the computer dispersion modeling;
- Descriptions of the modeling methods used; and
- Results of the air quality modeling.

1.2 REGULATORY FRAMEWORK

1.2.1 Applicable Air Quality Regulations

Air quality permitting in Alaska is conducted by the Alaska Department of Environmental Conservation. The Quartz Hill facilities will require a Permit to Operate in accordance with the Alaska Administrative Code (AAC), Title 18, Section 50.300.

For permitting purposes, the Tunnel Creek operations and the mine site operations are considered to be separate facilities (ADEC 1985). The two operations will therefore require separate air quality permits from ADEC. The air quality regulations that apply to the two operations are described in the following sections.

1.2.2 Air Quality Regulations Applicable to Tunnel Creek

The emissions of nitrogen oxides (NO_x) from the power plant stack will exceed 250 tons per year (tpy); therefore, the Tunnel Creek facility will be subject to Prevention of Significant Deterioration (PSD) review according to 18 AAC 50.300(a)(6). As discussed in Section 2.0, the emission rates for carbon monoxide, sulfur dioxide, nitrogen oxides, and volatile hydrocarbons will exceed the de-minimus limits specified in 18 AAC 50.300(a)(6)(C). Therefore, only those pollutants will be subject to PSD review. It is important to note that fugitive dust will not be subject to PSD review, because the predicted emission rates are less than the 25 tpy de-minimus level.

The PSD review for the Tunnel Creek facility will require the following analyses:

- USB must demonstrate that the sulfur dioxide emissions from the power plant will not cause increases in the existing background concentrations in excess of the PSD Class II increments shown in Table C-1-1. PSD increments have been established only for sulfur dioxide and particulate matter.

- USB must demonstrate that the combined emissions from all sources will not result in ambient concentrations, including existing background values, above the Alaska Ambient Air Quality Standards shown in Table C-1-2.

- USB must conduct Best Available Control Technology analyses to show that the emission controls they propose to use result in the maximum degree of reduction of each pollutant, taking into account energy, environmental, and economic impacts.

- USB must demonstrate that the construction and operation of the mine will not cause adverse impacts to visibility, vegetation, and soils.

The air quality regulations will apply at the project boundary that has been established by EPA Region 10 (EPA 1985b). The air quality boundary is shown in Figure C-1-1.

The EPA recently set allowable limits for PM-10 particulates (particles smaller than 10 microns). The new PM-10 limits are 150 ug/m^3 and 50 ug/m^3 for the 24-hour and annual averaging times, respectively. The new PM-10 limits replace the previous TSP limits for ambient standards. However, the previous PSD increments for TSP remain the same as they were prior to the PM-10 regulations.

1.2.3 Air Quality Regulations Applicable to the Mine Site

There are no major point emission sources at the mine site, so the operations there will not be subject to PSD review. The mining operations will therefore require only a Permit to Operate under 18 AAC 50.300. The air quality review for the mine operations will require the following:

TABLE C-1-1

PSD CLASS II INCREMENTS [a/],[b/]

(Concentrations in ug/m^3)

Pollutant	3-Hour[c/] Average	24-Hour[c/] Average	Annual Mean
TSP[d/]	None	37	19 (geometric)
SO_2	512	91	20 (arithmetic)

a/ Source: AAC 50.020(b)(2)

b/ No increments established for CO, O_3, NO_x, or Pb.

c/ Allowed to be exceeded once per year.

d/ TSP increments do not apply to either the Tunnel Creek nor mine site operations.

TABLE C-1-2

ALASKA AMBIENT AIR QUALITY STANDARDS

(Concentrations in ug/m^3)

Pollutant	1-Hour[a] Average	3-Hour[a] Average	8-Hour[a] Average	24-Hour[a] Average	Annual Mean
TSP	None	None	None	150	60[b]
SO_2	None	1,300	None	365	80[c]
CO	40,000	None	10,000	None	None
O_3	235	None	None	None	None
NO_x	None	None	None	None	100[c]
Pb	None	None	None	None	1.5[d]

a/ Allowed to be exceeded once per year.

b/ Geometric mean.

c/ Arithmetic mean.

d/ Quarterly arithmetic mean.

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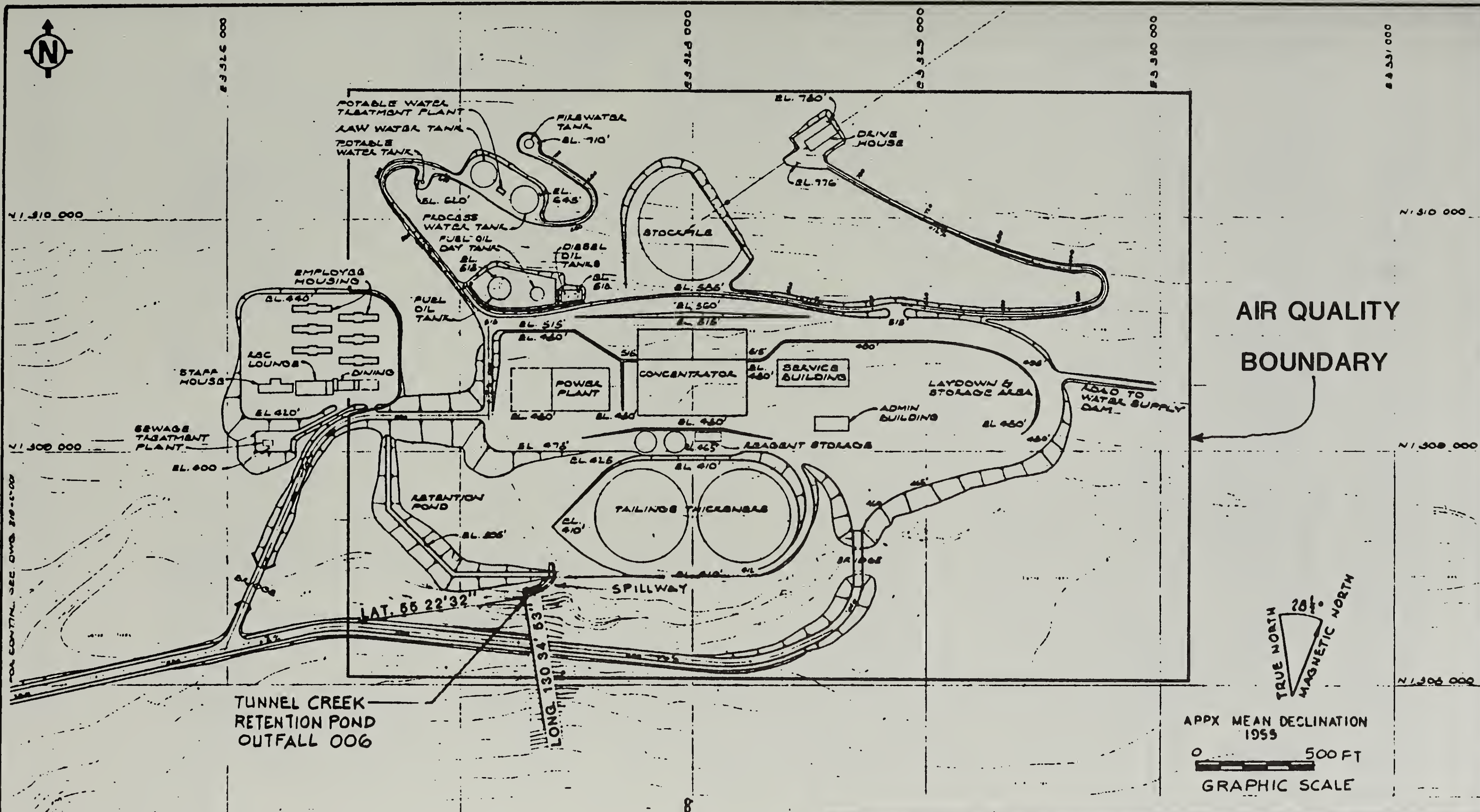

U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE QUARTZ HILL MOLYBDENUM PROJECT MINE DEVELOPMENT EIS	FIGURE C-1-1
PLOT PLAN AND AIR QUALITY BOUNDARY AT TUNNEL CREEK MILL SITE	envirosphere company A Division of EBASCO SERVICES INCORPORATED
SOURCE EPA 1985 DATE	

Note:
Grid shown is Alaska State Plane Coordinate System, Zone 1.

- The combined emissions from all sources cannot cause ambient concentrations higher than the Alaska State Ambient Air Quality Standards, which are listed in Table C-1-2.

- Emissions from the primary ore crusher cannot exceed the concentrations listed in the federal New Source Performance Standards for Metallic Mineral Processing Plants, Federal Register Vol. 47, No. 164, August 24, 1982.

The air quality standards at the mine site will apply at the air quality boundary specified by the Alaska Department of Environmental Conservation (Kelton 1986). The air quality boundary is shown in Figure C-1-2.

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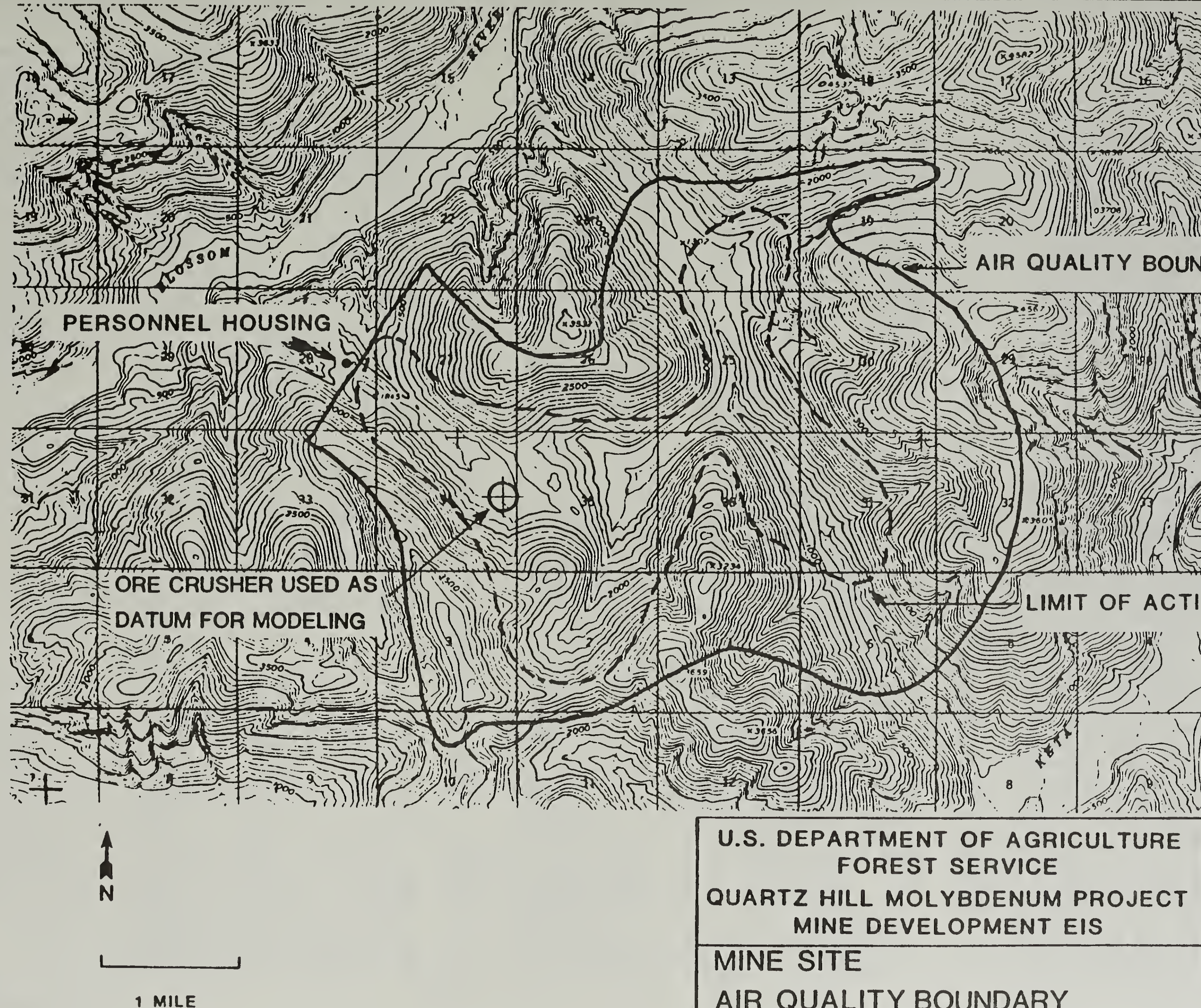

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

MINE SITE
AIR QUALITY BOUNDARY

SOURCE DATE

FIGURE C-1-2

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2.0 EMISSION INVENTORY

Sources of air pollutants will include facilities located in the Tunnel Creek valley, the Quartz Hill mine site, and the Wilson Arm wharf as indicated in Figure C-2-1. Tunnel Creek emissions will include the stack emissions from the combined cycle gas turbine power plant, concentrator emissions, the emissions from the ore stockpile loading operations, and fugitive dust from the haul road. Emissions from the mine site include those for mining activities, work residences, the ore-crusher, and service buildings. The emissions from the Wilson Arm wharf are from fuel storage tanks and periodic visits of aircraft and seagoing vessels.

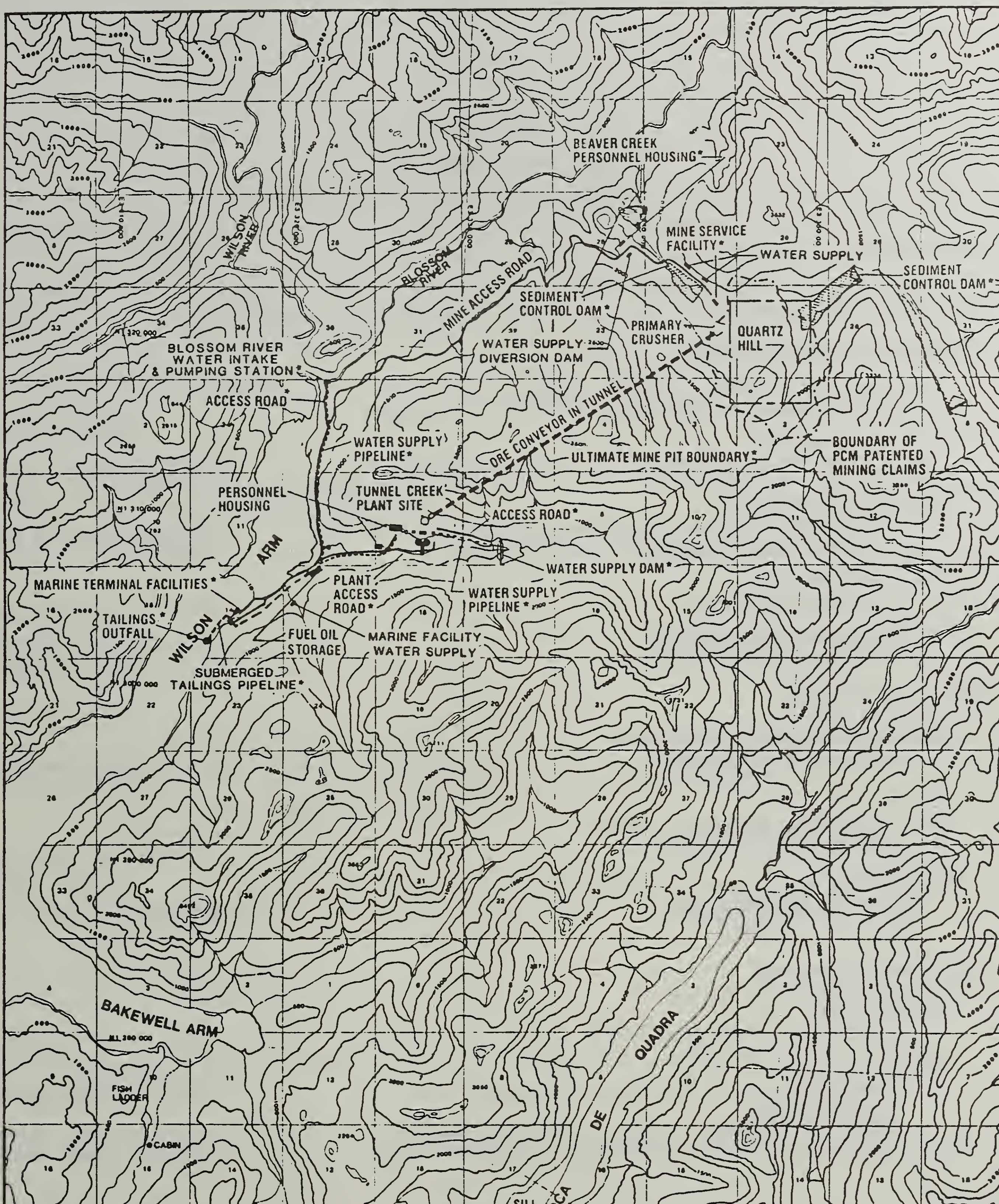
2.1 ASSUMED MINING OPERATIONS AND EMISSION FACTORS

In all cases, the proposed operations that were assumed to calculate the pollutant emission rates were provided to Envirosphere by U.S. Borax. The engineering values for the proposed project (for example, truck sizes, haul road lengths, etc.) are included in the following documents: The 1983 Draft Prevention of Significant Deterioration Permit Application from USB to ADEC; the 19 June 1984 responses by USB to the ADEC comments on the 1983 Permit Application; the August 1986 Final PSD and Air Quality Permit to Operate Application from USB to ADEC; and in Appendix A, "Description of the Proposed Project" of the 1984 Draft EIS by Envirosphere.

The emission factors and assumed mitigation measures are summarized in Table C-2-1. The emission factors used in the calculation of fugitive dust emissions include the Fourth Edition of "Compilation of Air Pollutant Emission Factors," September 1985 (U.S. Environmental Protection Agency 1985); and "Fugitive Particulate Emissions," Colorado Department of Health, July 2, 1984.

2.2 NATURAL MITIGATION FACTORS FOR FUGITIVE DUST REDUCTIONS

For these calculations, three classes of fugitive dust emissions were developed: (1) Uncontrolled emissions; (2) Maximum 24-hr emissions; and (3) Annual Average emissions. The Uncontrolled emissions would occur on a dry day with no controls other than natural deposition of large particles. Maximum 24-hr emissions assume dry conditions, with mitigation measures such as water sprays as appropriate. The Annual Average emissions account for natural fugitive dust reductions due to snow and rainfall. Based on the available on-site weather data (VTN 1980, 1981, 1982) and snow and avalanche studies (Wilson 1980), it is assumed there is snow cover for 182 days per year. Of the remaining 183 days, there is rain (precipitation exceeding 0.01 inches) on 114 days, and there are 69 days with no rain.


BEAVER CREEK
PERSONNEL HOUSING*
MINE SERVICE
FACILITY*
WATER SUPPLY
SEDIMENT
CONTROL DAM*
WILSON RIVER
BLOSSOM RIVER
MINE ACCESS ROAD
SEDIMENT
CONTROL DAM*
PRIMARY
CRUSHER
QUARTZ
HILL
WATER SUPPLY
DIVERSION DAM
BLOSSOM RIVER
WATER INTAKE
& PUMPING STATION*
ACCESS ROAD*
WATER SUPPLY
PIPELINE*
ORE CONVEYOR IN TUNNEL
ULTIMATE MINE PIT BOUNDARY*
BOUNDARY OF
PCM PATENTED
MINING CLAIMS
PERSONNEL
HOUSING
TUNNEL CREEK
PLANT SITE
ACCESS ROAD*
WATER SUPPLY DAM*
ARM
MARINE TERMINAL FACILITIES*
PLANT
ACCESS
ROAD*
WATER SUPPLY
PIPELINE*
TAILINGS
OUTFALL*
WILSON
FUEL OIL
STORAGE
MARINE FACILITY
WATER SUPPLY
SUBMERGED
TAILINGS PIPELINE*
BAKEWELL ARM
FISH
LADDER
CABIN
QUADRA
DE
BOCA
SILL
BAKEWELL LAKE
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
LOCATIONS OF FACILITIES FOR TUNNEL
CREEK MILL WITH WILSON ARM
TAILINGS DISPOSAL ALTERNATIVE
SOURCE U.S. Borax
DATE 1988
FIGURE
C-2-1
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company
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INCORPORATED

TABLE C-2-1

EMISSION SOURCES, FACTORS, AND REFERENCES

Emission Source and Factor	Reference
Tunnel Creek Valley Sources	
Combined Cycle Power Plant	
Particulate Matter (PM) 0.01 wt percent particulate in fuel oil. No mitigation.	U.S. Borax 1984
Sulfur Dioxide (SO_2) 0.05 wt percent sulfur in fuel oil. No mitigation.	U.S. Borax 1984
Nitrogen Dioxide (NO_2) 100 percent conversion of fuel bound nitrogen, plus 153 lbs/hr of thermal NO_x. Mitigation by water injection.	Turbine vendors and AP-42 Table 3.3.1-3
Carbon Monoxide (CO) 15.4 lbs/1,000 gallons	AP-42 Table 3.3.1-2 (EPA 1977)
Volatile Organic Carbon (VOC) 5.57 lbs/1,000 gallons of oil	AP-42 Table 3.3.1-2 (EPA 1977)
Coarse Ore Stockpile	
Load in by Conveyor Transfer Point $k(0.0018)\frac{(S/5)(U/5)(H/10)}{(M/2)^2}$	Colorado Dept. Health 1984, p. 42
Wind Erosion from coarse ore stockpile $1.7(S/1.5)(365-p/235)(f/15)$	Colorado Dept. Health 1984, p. 43
Loadout from Ore Stockpile to concentrator, $k(0.0018)\frac{(S/5)(U/5)(H/10)}{(M/2)^2}$	Colorado Dept. Health 1984, p. 42
Concentrator Access Road	
Fugitive Dust $E.F. = 0.077\ I(4/n)(s/10)(L/1{,}000)(W/3)^{0.7}$	AP-42, Section 11.2.6
Exhaust Emissions Tractor Trailers, CO=10.91 g/mi, HC=2.65 g/mi, and NO_x=5.43 g/mi	EPA-460/3-81-005, March 1981
Buses, CO=10.91 g/mi, HC=2.65 g/mi, and NO_x=5.43 g/mi	EPA-460/3-81-005, March 1981
Pickups, HC=0.8 g/mi, CO=10.0 g/mi, NO_x and PM=0.26 g/mi	EPA-460/3-81-005, March 1981

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TABLE C-2-1 (Continued)

EMISSION SOURCES, FACTORS, AND REFERENCES

Emission Source and Factor	Reference
Petroleum Storage Tanks	
Fuel Oil Tanks and Diesel Fuel Storage	
Breathing losses = $2.26 \times 10^{-2}\ M\ [P/(14.7-p)]^{0.68} D^{1.73} H^{0.51}\ T^{0.5}\ F_p C K_c = L_B$	AP-42 Section 4.3 (EPA 1977)
Working losses = $2.40 \times 10^{-2}\ MPK_nK_c$	
Mining Operation Sources	
Drilling of Ore and Waste Rock	
1.3 lbs of suspended particulate matter per hole. Mitigation of 75 percent with water injection	AP-42 Table 8.24-4 (EPA 1977)
Blasting of Ore and Waste Rock	
lbs/blast = $961\ A^{0.8}/\ D^{1.8}\ M^{1.9}$	AP-42 Table 8.24.1 (EPA 1977)
Waste Rock Removal	
$\frac{k(0.0018)(S/5)(U/5)(H/5)}{(M/2)^2(Y/6)^{0.33}}$	Colorado Dept. Health 1984
Waste Rock Haulroad	
Fugitive Dust	
E.F. = $k(5.9)(s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5}$ Mitigation by chemical suppressants = 85 percent	Colorado Dept. of Health 1984, p. 31
Exhaust Emission	
NO_x=7.63g/hphr, HC=0.12g/hphr, CO=1.09g/hphr, PM=0.25g/hphr	Cummins Engine Co.
Waste Rock Dumping	
Fugitive Dust	
$\frac{k(0.0018)(S/5)(U/5)(H/5)}{(M/2)^2(Y/6)^{0.33}}$	Colorado Dept. Health 1984
Waste Rock Stockpile Wind Erosion	
k(.0018)(S/1.5)(365-p/235)(f/15)	Colorado Dept. Health 1984
Ore Removal	
0.01 lbs/ton of rock for high moisture material $\frac{k(0.0018)(S/5)(U/5)(H/5)}{(M/2)^2(Y/6)^{0.33}}$	Colorado Dept. Health 1984

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TABLE C-2-1 (Continued)

EMISSION SOURCES, FACTORS, AND REFERENCES

Emission Source and Factor	Reference
Ore Haulroad	
Fugitive Dust	
E.F. = $k(5.9)(s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5}[(365-p)/365]$	Colorado Dept. of Health 1984,
Mitigation using chemical suppressants = 85 percent	p. 31
Exhaust Emissions	
NO_x=7.63g/hphr, HC=0.12g/hphr, CO=1.09g/hphr, PM=0.25g/hphr	Cummins Engine Co.
Primary Crushing of Ore	
0.004 lbs/ton	Colorado Dept. Health 1984, p. 23
Baghouse, 95 percent	
Petroleum Storage Tanks	
Diesel Fuel and Unleaded Gasoline Storage	
Breathing losses = 2.26×10^{-2} M $[P/(14.7-p)]^{0.68}$ $D^{1.73}$ $H^{0.51}$ $T^{0.5}$ $F_pCK_c = L_B$	AP-42 Section 4.3 (EPA 1977)
Working losses = 2.40×10^{-2} $MPK_nK_c = L_W$	AP-42 Section 4.3 (EPA 1977)
Residences and Other Building Heating	
No. 2 fuel oil emissions in lb/1000 gal; PM=2, SO_2=140S, CO=5, HC=1 and NO_x=22	AP-42 Table 1.3.1 (EPA 1977)
<u>Wilson Arm Wharf Sources</u>	
Petroleum Storage Tanks	
Diesel Fuel No. 2 and Unleaded Gasoline Storage	
Breathing losses = 2.26×10^{-2} M $[P/(14.7-p)]^{0.68}$ $D^{1.73}$ $H^{0.51}$ $T^{0.5}$ $CK_c = L_B$	AP-42 Section 4.3 (EPA 1977)
Working losses = 2.40×10^{-2} $MPK_nK_c = L_W$	AP-42 Section 4.3 (EPA 1977)
Sea-Going Vessels and Aircraft	
Monohull Crew Boat, emissions in lbs/1000 gal; SO_x=27, CO=100, HC=50, and NO_x=280 (PM=not available)	AP-42 Table 3.2.3-1 (EPA 1977)
Plane (Piper Warrior for a DeHavilland Beaver), emissions in lbs/1000 gal; CO=14.37, NO_x= 0.02, and HC-0.26 (PM=not available	AP-42 table 3.2.1-9 (EPA 1977)
Helicopter (25 percent of Huey for a Bell Jet Ranger), emission in lbs/1000 gal; CO=0.4, NO_x= 0.3, and HC-0.6 SO_2=0.05 (PM=not available)	AP-42 Table 3.2.1-8 (EPA 1977)
Sea-Going Barge (2,500hp tug), emissions in lbs/1000 gal; CO=59.8, HC=22.6, and NO_x=419.6; PM = 110; SO_2 = 41	AP-42 Table 3.2.3-3 (EPA 1977) EPA 1977

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TABLE C-2-1 (Continued)

EMISSION SOURCES, FACTORS, AND REFERENCES

Emission Source and Factor	Reference
Local Barge/Tug (900 hp), emissions in lbs/1000 gal; CO=62.2, HC=16.8, and NO_x=167.2; PM = 110; SO_2 = 41	AP-42 Table 3.2.3-3 (EPA 1977) EPA 1977
Tanker (35,000 DWT), emissions in lbs/1000 gal;	
Housekeeping mode: PM=19.05, SO_2=80s, CO=0.6, HC=2.54, and NO_x=35.6 (avg.)	Department of the Interior (1983)
Cruise mode: PM=19.05, SO_2=80s, CO=0.6, HC=2.94, and NO_x=50.24	

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Based on assumed mitigation measures and the known weather conditions, the annual average fugitive dust emissions for the key mining operations are quantified by calculating "penetration factors" as shown below. The "penetration factors" estimate the fraction of the total emissions that are not eliminated by natural and man-made controls.

2.2.1 Ore Removal, Loading, and Dumping

The ore to be mined is considered to be a high moisture content material, since its moisture content exceeds 4 percent weight of water. This factor is present in Colorado Department of Health and AP-42 emission estimates. The factor will also be applied to the waste rock.

2.2.2 Unpaved Haul Roads

For the unpaved haul roads the following penetration factor can be calculated assuming the addition of chemical suppressants.

Snow cover = 182 days = 100 percent mitigation
Rain = 114 days = 100 percent mitigation
Dry days = 69 days = 85 percent mitigation (by applied chemical suppressants)

The following Annual Average penetration factor is then calculated.

Annual Avg. penetration = 182(0)/365 + 114(0)/365 + 69(0.15)/365
= 0.0284

The Annual Average emissions are calculated by multiplying the Uncontrolled value by the 0.0284 average penetration factor.

On unpaved haul roads it is assumed that chemical suppressants such as magnesium chloride (MgCl) or Coherex, will be used in order to achieve a mitigation of 85 percent. For Coherex this involves an initial application rate of 1 gallon per square yard at a dilution rate of 1 to 4, and a road maintenance application rate of 1/2 gallon per square yard at a dilution rate of 1 to 10. This is based on EPA Region VIII data.

2.2.3 Paved Haul Roads

For paved haul roads the following penetration factor can be calculated:

Snow Cover = 182 days = 100 percent mitigation
Rain = 114 days = 100 percent mitigation
Dry days = 69 days = 50 percent mitigation (water spray)

Annual Average Penetration = 182(0)/365 + 114(0)/365 + 69(0.50)/365
= 0.0945

The Annual Average emissions are calculated by multiplying the uncontrolled value by the 0.0945 penetration factor.

It is felt that the 100 percent reduction of dust emissions due to rain, snow, and snow cover on both paved and unpaved roads is appropriate based on the large amount of precipitation (rain and snow) in the area as indicated below.

Month	Accumulated Snow Depth (inches)1/	Rainfall (inches)2/
Jan	129	-
Feb	152	-
Mar	148	-
Apr	122	-
May	-	4.6
Jun	-	5.4
Jul	-	7.3
Aug	-	8.1
Sep	-	14.6
Oct	-	21.3
Nov	12	-
Dec	94	-
	Total Summer Rainfall	61.3

1/ Data for 1978-79
2/ Data for 1976-82

Further, this precipitation offers a constant source of moisture not just on the roads, but the surrounding area as well.

2.2.4 Wind Erosion from Active Stockpiles

For the waste rock stockpiles and the crushed ore stockpile, the following natural mitigations were assumed:

Snow cover = 182 days = 100 percent mitigation
Rain = 114 days = 50 percent mitigation
Dry Days = 69 days = No reduction

Annual Average Penetration =
$182(0)/365 + 114(0.50)/365 + 69(1.0)/365 = 0.345$

2.3 TUNNEL CREEK VALLEY SOURCES

Pollutants will be emitted from the power plant, from the coarse ore storage stockpile at the portal of the conveyor tunnel, and from the vehicles on the haul road. The concentrator operations are wet so there will be no emissions from this facility. Operations are assumed to take place 365 days per year even though the facility could average

10 days of downtime in any year. Stack emissions and fugitive dust emissions will be quantified for the following sources at the Tunnel Creek Valley area:

- o Combined Cycle Gas Turbine Power Plant
- o Coarse Ore Stockpile
- o Concentrator Access Road
- o Petroleum Storage Tanks

2.3.1 Combined Cycle Gas Turbine Power Plant

In this section, the emissions of particulate matter (PM), sulfur dioxides (SO_2), nitrogen dioxides (NO_2), carbon monoxide (CO), and volatile organic carbons (VOCs) are evaluated for the 80,000 kW combined cycle gas turbine power plant burning No. 2 diesel fuel. Also presented is information on the number of stacks, stack height, and exhaust temperature for use in modeling. Emissions for the 44,000 kW power plant are also presented.

Fuel Characteristics

Before any emission calculations can be made the fuel must be characterized for ash content, sulfur content, and nitrogen content. The following is a review of fuel characteristics, potential suppliers of fuel, and types of long-term supply commitments.

Tosco Corporation would be the primary supplier of fuel for the Quartz Hill power plant. They can provide a special arctic fuel oil that has a 0.05 percent sulfur content, with basic nitrogen at 108 PPM and total nitrogen at 894 PPM. The price would be $0.50 per barrel less than the price of regular Westcoast No. 2 diesel fuel. Tosco is willing to commit to a 10-year contract for supply of this fuel oil, and use regular No. 2 diesel as an emergency backup fuel. Price escalation and de-escalation would be based strictly on what happens to the base price of No. 2 diesel fuel. The current delivered price to Quartz Hill is $0.78 per gallon, or $5.29/MMBtu.

Tesoro Petroleum Company would be the second choice to provide No. 2 diesel fuel with a guarantee that their fuel would not exceed 0.15 percent maximum sulfur content. The current price delivered to Quartz Hill is $0.82 per gallon, or $5.94/MMBtu. They are also interested in committing to a 10-year supply contract. They would provide fuel from their Cook Inlet, Alaska, facility and equalize freight from the Seattle area.

The third source is Mobil Oil, who also would guarantee the 0.15 percent maximum sulfur content requirement and who are also interested in a 10-year supply contract.

Other suppliers, such as Chevron and Union Oil, produce many kinds of distillate oil. All of these distillate oils are in conformity with the basic ASTM specifications, which call for 0.5 percent maximum sulfur content and about 2,000 to 3,000 PPM of chemically-bound nitrogen. The fuel-bound nitrogen is not a criterion for their products.

To be in compliance with legislation in the Los Angeles area, in January 1985 the fuel producers will be producing and selling a No. 1 diesel fuel oil with a maximum sulfur content of 0.05 percent. This fuel is intended for diesel engine automobiles only. There presently is no information available about the nitrogen content. The cost of this product is estimated to be about $0.06 to $0.07 per gallon more than regular diesel fuel.

All of the above-mentioned fuels contain less than 0.01 percent ash.

Power Plant Fuel Usage

For the 80,000 tpd mining operations, the power plant will be operated at an average load of 67,000 kW. The expected power plant usage is 355 days per year with 90 percent utilization. The estimated fuel usage for the 80,000 tpd mining operations is 38.4 million gallons per year.

Particulate Matter Emissions

Particulate matter emissions from the 80,000 kW gas turbines are calculated based on the weight of No. 1 and No. 2 fuel oil, which is approximately 7.5 lbs/gal; the weight of particulate matter (ash) in the oil of 0.01 percent; and an assumed rate of removal due to scaling in the turbine of 5 percent. The 5 percent factor was provided by equipment vendors, and represents the value that is normally encountered with good equipment operation and maintenance.

Particulate matter emission rates have been calculated using vendor-provided upper limits on ash and trace metals content of the oil. The particulate matter emissions are calculated as indicated below:

Particulate Matter (PM)

= (scale factor)(ash content)(fuel usage)(density)(1 tons/2000 lb)

= $(1-0.05)(0.0001)(38.4\times10^{6}$ gals oil/yr)(7.5 lbs oil/gal)(1 tons/2000 lbs)

= 13.7 tons/yr, or

= 3.6 lbs/hr

Sulfur Dioxide

The calculation of the sulfur dioxide emission rate is based on an emission factor of 140S lbs/1000 gals of oil (where S is the percent sulfur content) as indicated in AP-42, Table 3.3.1-2, of Section 3.3.1 titled "Stationary Gas Turbines for Electric Utility Power Plants." The calculations are indicated below for S = 0.05 percent:

SO_2 Emissions

= (140[0.05] lbs/1000 gals oil)(38.4x10^6 gals oil/yr)(1 tons/2000 lbs)

= 134.5 tons/yr, or

= 30.5 lbs/hr

Nitrogen Dioxide

Because the oxides of nitrogen emission factor from AP-42 appears general, more specific information based on the fuel characteristics is used.

The Tosco Corporation special arctic fuel has total nitrogen of 894 PPM. Assuming that all of this fuel bound nitrogen (FBN) is converted to NO_2, the following FBN emission factor is calculated:

$$\text{Emission factor} = \frac{\text{mol. wt. } NO_2}{\text{mol. wt. N}} (\text{PPM FBN} \times 10^{-6})$$

$$= \frac{46}{14} (894 \times 10^{-6})$$

= 0.00294 lbs FBN/lb fuel consumed

For the 80,000 kW power requirement, approximately 32,680 lbs/hr or 4,358 gals/hr of fuel will be consumed. Therefore, 96.1 lb NO_x/hr due to FBN will be emitted.

Additionally, 153 lbs/hr of thermal NO_x will be generated due to the thermal conversion of nitrogen in the combustion air to NO_x. This reflects BACT of 79 percent controls that the vendor has specified based on a water-to-fuel injection rate of 1.0 for NO_x reduction. The 79 percent control factor is obtained from AP-42, Table 3.3.1-3.

The emission rate of oxides of nitrogen is then the sum of fuel-bound NO_x and thermal NO_x as presented below.

Total NO_2
= (96.1 lbs FBN + 153 lbs thermal)(7,668 hrs/yr)(1 tons/2,000 lbs)
= 955 tons/yr, or
= 217.5 lbs/hr

Carbon Monoxide

The calculation of carbon monoxide emission is based on an emission factor of 15.4 lbs/1000 gals of oil as indicated in AP-42, Table 3.3.1-2. The calculations are presented below:

CO (tons/yr)
= (15.4 lbs/1000 gals oil)(38.4x10^6 gals/yr)(1 tons/2000 lbs)
= 293.9 tons/yr, or
= 67.2 lbs/hr

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Volatile Organic Carbons

The calculations of volatile organic carbon emission are based on an emission factor of 5.57 lbs/1000 gals of oil as indicated in AP-42, Table 3.3.1-2. The calculations are presented below:

VOC (tons/yr)

$= (5.57 \text{ lbs/1000 gals oil})(38.4\times10^6 \text{ gals/yr})(1 \text{ tons/2000 lbs})$

$= \underline{106.7 \text{ tons/yr}}$, or

$= \underline{24.2 \text{ lbs/hr}}$

Stack Parameters

Although the stack parameters are not used for the calculations of the emission rates of the combined cycle gas turbine power plant, they are nonetheless presented for use in the computer modeling of the emission impacts.

Exit Temperatures:

The temperature of the exhaust from the gas turbine will be about 1000°F. This gas will be routed through heat recovery steam generators (HRSG) to reduce the temperature to about 350°F. The exhaust gases are further cooled from 350°F down to 300-310°F during transport up the stack. The natural draft available from the thermal buoyancy of the gas provides the driving force for the exhaust gases between the gas turbine outlet and the stack exit. Exhaust velocities are typically 20 to 50 feet per second (fps).

Stack Height:

Changes were made during the engineering feasibility study in the configuration of the facilities proposed for Tunnel Creek Valley, in the dimensions of the various buildings, in the number of stacks for the power plant (from three to one), and in the location of the stack. Accordingly, a new stack height was calculated using good engineering practice (GEP) guidelines:

$$h = h_b + 1.5\ l_b$$

where

h = GEP stack height

h_b = height of highest nearby building that is within 2-3 building heights of the stack

l_b = smaller of the width or height of this building

In this case, the concentrator building, which is designed to be 160 ft high and 325 ft wide, was the dominating building as it was only about 300 ft from the proposed stack location. Since the height of the building is the smaller value, the GEP stack height for the power plant stack was calculated using it as indicated below:

$h \text{ (ft)} = 160 \text{ (ft)} + 1.5 \text{ (160 ft)}$

$h = \underline{400 \text{ ft}}$

With the selection of one 400-ft stack for the power plant, the stack diameter and flue gas exit parameters are as follows:

Parameters	Value
Stack height	400 ft
Stack diameter	16 ft
Exit temperature	305°F
Exit velocity	50 fps

2.3.2 Coarse Ore Stockpile

Approximately 80,000 tpd of coarse ore will be transported by tunnel conveyor to the live storage pile at the concentrator. The estimated silt content of the crushed ore is 0.25 percent, and the estimated moisture is 5 percent (U.S. Borax 1985). Load-in to the coarse ore storage pile will be by a transfer point while load-out from the storage pile will be by bottom-feed, enclosed conveyor with the emissions controlled by either wet scrubbers or a baghouse.

Load-in by Conveyor Transfer Point

Crushed ore will be stockpiled using a radial stacker. The fugitive dust will be controlled using water sprays, with an assumed reduction of 70 percent (Colorado Dept. Health 1984, p. 47). The uncontrolled emission factor is as follows (Colorado Dept. Health, p. 42).

$$EF\ (\text{lbs/ton}) = k(0.0018)\frac{(S/5)(U/5)(H/10)}{(M/2)^2}$$

k = 30 um size parameter, 0.77
S = silt content, 0.25 percent
U = wind speed, assumed 3.5 mph
H = drop height, 60 ft
M = moisture content, 5 percent

$$EF = 0.77(0.0018)(0.25/5)(3.5/5)(60/10)/(5/2)^2$$
$$= 4.7 \times 10^{-5}\ \text{lbs/ton}$$

Assuming a 70 percent mitigation, the maximum 24-hr emission rate is:

$$(80{,}000\ \text{tpd})(4.7 \times 10^{-5}\ \text{lbs/ton})(1-0.70)(1/24) = \underline{0.05\ \text{lbs/hr}}$$

The annual average emission rate is:

$$(0.05\ \text{lbs/hr})(8{,}760\ \text{hrs/yr})(1/2000) = \underline{0.21\ \text{tons/yr}}$$

Coarse Ore Stockpile Loadout

Loadout of the coarse ore will be by bottom feed enclosed conveyors, with emission control by wet scrubbers or a baghouse. The assumed mitigation efficiency is 95 percent. The uncontrolled emission factor is conservatively assumed to be the same as that for the radial stacker (4.7×10^{-5} lbs/ton). The worst case 24-hr emissions are:

$(80,000 \text{ tpd})(4.7 \times 10^{-5} \text{ lbs/ton})(1-0.95)(1/24) = \underline{0.0077 \text{ lbs/hr}}$

The annual emission rate is:

$(0.0077 \text{ lbs/hr})(8,760 \text{ hrs/yr})(1/2000) = \underline{0.034 \text{ tons/yr}}$

<u>Coarse Ore Stockpile Wind Erosion</u>

The ore stockpile will be 400 ft in diameter and 100 ft high, with an exposed area of roughly 4.5 ac. The uncontrolled emission factor is as follows (Colorado Dept. Health 1984, p. 43):

$$EF \text{ (lbs/ac/day)} = 1.7\ (S/1.5)(365-P/235)(F/15)$$

- S = silt content, 0.25 percent
- P = precipitation factor, 0 for dry day
- F = frequency of winds exceeding 12 mph, 2.43 percent for C stability (See Table C-3-12)

$$EF = 1.7\ (0.25/1.5)(365/235)(2.43/12) = 0.072 \text{ lbs/ac/day}$$

The worst case 24-hour emissions are:

$(0.072 \text{ lbs/ac/day})(4.5 \text{ ac})(1/24) = \underline{0.014 \text{ lbs/hr}}$

Using the annual average penetration factor of 0.345 (See Section 2.2.4), the annual emissions are:

$(0.014 \text{ lbs/hr})(8,760 \text{ hrs/yr})(0.345)(1/2000) = \underline{0.020 \text{ tons/yr}}$

2.3.3 Concentrator Access Road

The 1.7-mi-long access road connecting the concentrator and the wharf will be asphaltic concrete. Traffic on the road will consist of the following:

- o Six trips of 18-wheeled tractor trailers per day to haul supplies to the concentrator and to haul concentrate to the wharf;
- o Two bus trips per day to deliver workers to the concentrator area and to return workers to the wharf; and
- o About 40 trips per day by pick-ups for miscellaneous errands.

Fugitive dust emission factor (E.F.) for travel on the access road is determined from AP-42, Section 11.2.6.

$$E.F. \text{ (lbs/vmt)} = 0.077\ I(4/n)(s/10)(L/1,000)\ (W/3)^{0.7}$$

- I = 1.0 dimensionless factor, applies for paved working areas
- n = number of traffic lanes, 2
- s = surface material silt content, assume 12.5 percent

L = surface silt loading, assume 250 lbs/mile based on 7.0 g/m^2 silt loading
W = mean vehicle weight, tons

The assumed values for s and L above are from AP-42 Table 11.2.6-1, for "Iron and Steel Production." The Tunnel Creek concentrator facility should be similar to a steel mill, so use of those characteristics is appropriate.

To account for rainfall and snow cover, the Uncontrolled emission rate was multiplied by the 0.0945 penetration factor (Section 2.2.3) to calculate the Annual Average emissions.

Tractor Trailer

Emissions were calculated assuming six trips/day, 3.4-mi round trip (wharf to concentrator), 365 days per year, or 7,450 mi/year. Solving the above equation for the following vehicle specific values yields the Maximum 24-hr and Annual Average emission rates. Here the Uncontrolled and Maximum 24-hr emission are equal.

W = 42.5 tons
w = 18 wheels

Maximum 24-hr:

$$\text{E.F. (lbs/vmt)} = 0.077\ (1.0)(4/2)(12.5/10)(250/1{,}000)(42.5/3)^{0.7}$$
$$\text{E.F.} = 0.31 \text{ lbs/vmt}$$

$$E = (0.31 \text{ lbs/vmt})(7{,}450 \text{ vmt})\left(\frac{1 \text{ ton}}{2000 \text{ lbs}}\right)$$

$= \underline{1.15 \text{ tons/yr}}$, or
$= \underline{0.27 \text{ lbs/hr}}$

Annual Average Emissions:1/

$= \underline{0.11 \text{ tons/yr}}$

Tailpipe Emissions:

The reference used for truck emissions is Compilation of Air Pollutant Emission Factors: Highway Mobile Sources (EPA-460/3-81-005, March 1981, Washington, D.C.) Table 1.7.1A, "Exhaust Emission Rates for Low Altitude 49 State Heavy Duty, and Diesel Powered Vehicles" (U.S. EPA 1981) for Calendar Year 1985.

1/ Obtained by multiplying Uncontrolled emissions by the 0.0945 factor (see Section 2.2.3).

Pollutant	Emission Factor (g/mile)	Tons/Yr
CO	10.91	0.24
HC	2.65	0.06
NO_x	5.43	0.12

Bus Traffic

Emissions were calculated assuming two round trips/day to the concentrator from the wharf, 3.4-mi round trip, 365 days per year, or 2,482 mi per year. Two trips/day to mine, 19.6-mi round trip, 365 days per year, or 14,308 mi per year. Total miles traveled is then 16,790. Solving the emission factor for the following vehicle-specific values yields the Maximum 24-hr and Annual Average emission rates.

W = 10 tons
w = 6 wheels
S = 20 mph

$$\text{E.F. (lbs/vmt)} = 0.077(1.0)(12.5/10)(250/1{,}000)(10/3)^{0.7}$$

and

Maximum 24-hr Emissions:

$$E = (0.11\ \text{lbs/vmt})(16{,}790\ \frac{\text{vmt}}{\text{yr}})(\frac{1\ \text{ton}}{2000\ \text{lb}})$$

$$= \underline{0.94\ \text{tons/yr}},\ \text{or}$$
$$= \underline{0.21\ \text{lbs/hr}}$$

Annual Average Emissions:1/

$$= \underline{0.09\ \text{tons/yr}}$$

Tailpipe Emissions:

Using emission factors for buses from Table 1.7.1A of EPA-460/3-81-005:

Pollutant	Emission Factor (g/mile)	Tons/Yr
CO	10.91	0.20
HC	2.65	0.05
NO_x	5.43	0.10

1/ Calculated by multiplying the Uncontrolled emission by the 0.0945 factor (see Section 2.2.3).

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Pickup Trucks

Emissions were calculated assuming 40 trips/day at 3.4 mi/round trip, 365 days per year, or 49,600 mi per year. Solving the emission factor equation for the following vehicle specific values yields the Maximum 24-hr and Annual Average emission rates.

Maximum 24-hr Emissions:

W = 2 tons
w = 4 wheels
S = 25 mph

$$\text{E.F. (lbs/vmt)} = 0.077(1.0)(4/2)(12.5/10)(250/1{,}000)(2/3)^{0.7}$$
$$0.04 \text{ lbs/vmt}$$

then

$$E = (0.04 \text{ lbs/vmt})(49{,}600 \frac{\text{vmt}}{\text{yr}})(\frac{1 \text{ ton}}{2000 \text{ lb}})$$

= 0.88 tons/yr, or
= 0.21 lbs/hr

Annual Average Emissions:1/

= 0.08 tons/yr

Tailpipe Emissions:

Emissions from light-duty trucks are calculated using Table A.1.2 in Compilation of Air Pollutant Emission Factors: Highway Mobile Sources (EPA-460/3-81-005, March 1981, Washington, D.C.).

Pollutant	Emission Factor (g/mile)	Tons/Yr
HC	0.8	0.11
CO	10.0	1.37
NO_x	0.9	0.12
PM	0.26	0.04

1/ Calculated by multiplying the worst case 24-hr emission by the 0.0945 factor (see Section 2.2.3).

Total emissions from the tractor trailers, buses, and pickup trucks, are presented below:

Emission	Tractor Trailer	Bus	Pickup	Total
Fugitive Dust				
Maximum 24-hr (lbs/hr)	0.4	0.2	0.3	0.9
Annual Average (tons/yr)	0.2	0.1	0.1	0.4
Tailpipe				
Carbon monoxide (tons/yr)	0.24	0.20	1.37	1.81
Hydrocarbons (tons/yr)	0.06	0.05	0.11	0.22
Nitrogen Oxides (tons/yr)	0.12	0.10	0.12	0.34
Particulate (tons/yr)	--	--	0.04	0.04

2.3.4 Petroleum Storage Tanks

Minor hydrocarbon emissions will occur from the power plant fuel oil and diesel fuel tanks located in Tunnel Creek valley. Since these tanks will be of the fixed roof type, both breathing losses and working losses are emitted. In these cases the Uncontrolled, Maximum 24-hr, and Annual Average emission rates are equal.

Power Plant Fuel Storage

Each of the two power plant fuel oil tanks will have a 54,000 bbl (2.3×10^6) capacity, be 90 ft in diameter by 48 ft tall, have fixed roofs, and an average throughput of 24.2×10^6 gals/yr, replenished about every two weeks. Breathing and working emissions are calculated according to AP-42, Section 4.3.

Breathing Losses:

$$L_B = 2.26 \times 10^{-2} M \left(\frac{P}{14.7-P}\right)^{0.68} D^{1.73} H^{0.51} T^{0.5} F_p \, C \, K_c$$

where

- L_B = Fixed roof breathing losses in lbs/yr
- M = Molecular weight = 130 lbs/lb mole (No. 2 oil)
- P = True vapor pressure = 0.0045 psia (No. 2 oil)
- D = Tank diameter = 90 ft
- H = Average vapor space height = 8 ft
- T = Average ambient diurnal temperature change = 16°F
- F_p = Paint factor = 1.20 (specular aluminum)
- C = Adjustment factor for small tanks = 1.0
- K_c = Crude oil factor = 1.0

Inserting the above values into the equation results in calculated breathing losses of 400 lbs/year/tank. Total breathing losses for both tanks are indicated below.

0.1 lbs/hr, or
0.4 tons/yr

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Working losses are calculated as follows:

$$L_W = 2.40 \times 10^{-2}\ M\ P\ K_n\ K_c$$

where: L_W = Fixed roof working losses in lbs/10^3 gallon throughput
M = Molecular weight = 130 lbs/lb mole (No. 2 oil)
P = True vapor pressure = 0.0045 psia (No. 2 oil)
K_n = Turnover factor = 1.0 (10 annual turnovers)
K_c = Crude oil factor = 1.0

Inserting the above values into the equation results in calculated working losses per tanks of 0.01404 lbs/1000 gallons. Total losses are then calculated as follows:

(0.01404 lbs/1000 gal tank)(10 turnovers/yr)
(2.3 x 10^6 gals/turnover)(2 tanks)(1 tons/2000 lbs)

= 0.32 tons/yr, or
= <u>0.07 lbs/hr</u>

Diesel Fuel Storage

In the Tunnel Creek valley, diesel fuel will be stored in one 20,000 barrel (840,000 gal) capacity, 60 ft diameter by 40 ft tall, fixed roof tank with 1 x 10^7 gals per year throughput or 12 turnovers a year. Emissions are calculated according to AP-42 as previously indicated assuming that the emission factors of No. 2 fuel oil are similar to that of diesel fuel.

Breathing Losses:

$$L_B = 2.26 \times 10^{-2} M \left(\frac{P}{14.7-P}\right)^{0.68} D^{1.73}\ H^{0.51}\ T^{0.5}\ F_p\ C\ K_c$$

L_B= Fixed roof breathing losses in lbs/year
M = Molecular weight = 130 lbs/lb mole (No. 2 oil)
P = True vapor pressure = 0.0045 psia (No. 2 oil)
D = Tank diameter = 60 ft
H = Average vapor Space height = 5 ft
T = Average ambient diurnal temperature change = 16°F
F_p = Paint factor = 1.2 (Specular aluminum)
C = Adjustment factor for small tanks = 1.0
K_c = Crude oil factor = 1.0

Inserting the above values into the equation and dividing by 2000 lbs/ton results in calculated breathing losses of 157.8 lbs per year, as indicated below:

= 0.07 tons/yr, or
= <u>0.02 lbs/hr</u>

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Working losses are calculated as follows:

$$Lw = 2.40 \times 10^{-2} \; M \; P \; K_n \; K_c$$

where: Lw = Fixed roof working losses in lbs/10^3 gallon throughput
M = Molecular weight = 130 lbs/lb mole (No. 2 oil)
P = True vapor pressure = 0.0045 psia (No. 2 oil)
K_n = Turnover factor = 1.0 (10 annual turnovers)
K_c = Crude oil factor = 1.0

Inserting the above values into the equation results in calculated working losses of 0.01404 lbs/1000 gals. Total losses are calculated as follows:

=(0.01404 lbs/1000 gal tank)(12 turnovers/yr)(840,000 gals/turnover)
(1 tons/2000 lbs)

= 0.07 tons/yr, or
= 0.02 lbs/hr

2.4 QUARTZ HILL MINING OPERATION SOURCES

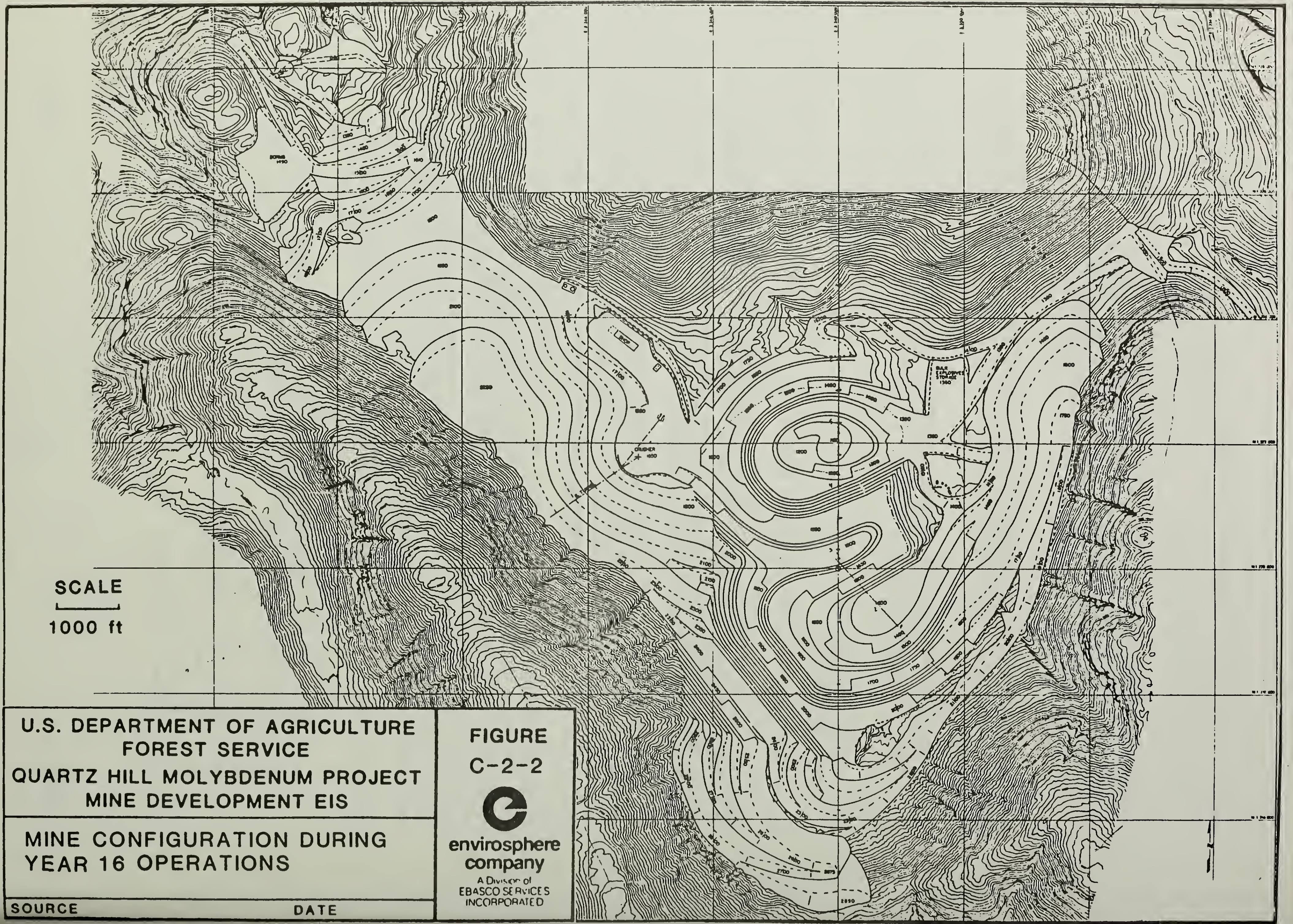
Emissions from mining operations will be chiefly fugitive dust from drilling, blasting, ore and waste rock loading and hauling, crushing operations, coarse ore conveying, and tailpipe emissions from the haul trucks. The mine site is shown in Figure C-2-2.

For each source presented below, a nominal mining rate of 80,000 tons of ore per day and 365 days per year has been assumed, although weather conditions could force a shutdown of mining operations such that activities will take place on the average of only 321 days each year.

Proposed mining operations through year 20 were reviewed to determine the year when maximum particulate emissions would be expected. The combination of ore and waste rock removal, haul distance, and haul truck speed resulted in the selection of year 16 as the year to model the emissions. For year 16, the waste rock to ore ratio has been established as 0.9. Thus, 72,000 tons of waste rock must be removed when mining 80,000 tons per day of ore.

Emissions are estimated for the following:

- Drilling of ore and waste rock
- Blasting of ore and waste rock
- Waste rock removal (loading)
- Waste rock haul road
- Waste rock dumping
- Waste rock stockpile wind erosion
- Ore removal (loading)
- Ore haul road
- Primary crushing of ore



U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

MINE CONFIGURATION DURING YEAR 16 OPERATIONS

SOURCE DATE

FIGURE C-2-2

envirosphere company
A Division of EBASCO SERVICES INCORPORATED

2.4.1 Drilling of Ore and Waste Rock

The emission factor for this activity is 1.3 lbs of suspended particulate per hole for overburden as presented in AP-42, Table 8.24-4. The emissions from this source will be controlled by water injection. According to the Colorado Department of Health, water injection accounts for a 75 percent control efficiency for the drilling of ore and waste rock. The Uncontrolled, Maximum 24-hr, and Annual Average calculated emission rates are presented below.

Uncontrolled Emissions:

$$\text{Number of holes} = \frac{\text{tons/day}}{\text{4000 tons/hole}} \times \text{365 days per year}$$

$$= \frac{\text{(80,000 tons ore + 72,000 tons waste rock) per day} \times \text{365 days}}{\text{4000 tons/hole}}$$

$$= \text{13,870 holes per year}$$

Then, the Uncontrolled emission rate is calculated.

$$E = \text{(1.3 lbs/hole)(13,870 holes/yr)(1 tons/2000 lbs)}$$

$$= \underline{\text{9.0 tons/yr}}\text{, or}$$
$$= \underline{\text{2.1 lbs/hr}}$$

Maximum 24-hr Emissions:

The Maximum 24-hr emission rate is calculated assuming a 75 percent reduction for water injection during drilling:

$$E = \text{(9.0 tons/yr)(1-0.75)}$$

$$= \underline{\text{2.2 tons/yr}}\text{, or}$$
$$= \underline{\text{0.5 lbs/hr}}$$

Annual Average Emissions:

The Annual Average emission rate is equal to the Maximum 24-hr emission rate since no mitigation is assumed for rain and snow cover.

2.4.2 Blasting of Ore and Waste Rock

The equation used for blasting was taken from AP-42, Table 8.24.1.

$$\text{E.F.} = 961\ A^{0.8} / D^{1.8}\ M^{1.9}\ \text{lbs/blast}$$

A = Area blasted = 38,912 ft^2 (based on a 32' x 32' spacing)
D = Depth of holes = 60 ft
M = Moisture content of ore/waste rock *in situ* = 4 percent

The Uncontrolled, Maximum 24-hr, and Annual Average calculated emissions are presented below.

Uncontrolled Emissions:

$$E.F. = (961)(38{,}912)^{0.8} / [(60)^{1.8}\ (4)^{1.9}]$$
$$= 204\ \text{lbs/blast}$$

Assuming one blast/day, the following emission rate is calculated:

$$E = (204\ \text{lbs/blast})(365\ \text{blasts/yr})(\ 1\ \text{tons}/2000\ \text{lb})$$
$$= \underline{37.2\ \text{tons/yr}},\ \text{or}$$
$$= \underline{8.5\ \text{lbs/hr}}$$

Maximum 24-hr Emissions:

The Maximum 24-hr emission rate is equal to the Uncontrolled rate since no mitigation is assumed.

Annual Average Emissions:

No mitigation is assumed for rain, snow cover, the presence of moisture on the rock working face, or groundwater seams. As a result, the Annual Average emission rate is equal to the Maximum 24-hr emission rate given above.

2.4.3 Waste Rock Removal

Waste rock and ore will be loaded into the haul trucks using loaders with 26-cu-yd buckets. The ore will have estimated silt and moisture contents of 0.25 percent and 4 percent, respectively (U.S. Borax 1985f). The emission factor for the waste rock and ore loading are as follows (Colorado Dept. Health 1984, p. 41):

$$E.F.\ (\text{lbs/ton}) = k(0.0018)\frac{(S/5)(U/5)(H/5)}{(M/2)^2(Y/6)^{0.33}}$$

k = 30 um size parameter, 0.73
S = silt content, 0.25 percent
U = wind speed, assume 3.5 mph
H = drop distance, 5 ft
M = moisture, 4 percent
Y = bucket size, 26 cu yd

$$E.F. = (0.73)(0.0018)\frac{(0.25/5)(3.5/5)(5/5)}{(4/2)^2(26/6)^{0.33}}$$

$$= 7.1 \times 10^{-6}\ \text{lbs/ton}$$

The Maximum 24-hour emissions are:

$$(72{,}000\ \text{tons/day})(7.1 \times 10^{-6}\ \text{lbs/ton})(1/24)$$
$$= \underline{0.021\ \text{lbs/hr}}$$

The annual emissions are:

(0.021 lbs/hr)(8,760 hrs/yr)(1/2000)
= 0.09 tons/yr

2.4.4 Waste Rock Haul Road

Waste rock will be hauled by 170-ton end dump trucks approximately 2.25 mi to the waste rock dump. Each truck has a tare weight of 115 tons and will average 164 tons of rock per trip, for a gross loaded weight of 279 tons. The haul road will be constructed of coarse gravel. Fugitive dust emissions for travel on the haul road are determined from AP-42, Section 11.2.1.

The haul roads will be constructed of coarse gravel. Waste rock or low grade ore will be crushed, then double screened to produce uniform gravel of 1" to 2" size. The gravel will be placed as needed over the large boulders in the mine and waste rock areas to provide a uniform road surface.

No tests have been performed to measure the silt content of the 1" to 2" haul road gravel. However, independent tests to measure the silt content of the undersized fraction smaller than 1" size were done earlier by U.S. Borax (U.S. Borax 1986). The small gravel will not be used as haul road gravel, and its silt content should be higher than the 1" to 2" gravel that will be used for the haul road. The silt content of the gravel smaller than 1" size ranged from 0.54 percent to 1.93 percent.

As a very conservative assumption, a silt content of 1.93 percent for the haul road gravel was used. The 1.93 percent value is the highest silt content that was measured for the undersized gravel that will specifically not be used for the haul roads. The silt content of the 1" to 2" haul road gravel is expected to be much less than 1.93 percent.

The average truck speed during the first 20 years of operation will be 11-18 mph, and 19 mph after that (Paulsen 1986). For these calculations, an average truck speed of 19 mph is assumed.

$$E.F. = k(5.9)(s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5} \text{ lbs/vmt}$$

k = 0.8 size multiplier (30 um)
S = mean vehicle speed, 19 mph
W = mean vehicle weight (115 + 279)/2 = 197 tons
w = mean number of wheels, 6
s = mean silt content, 1.93 percent

The unpaved haul roads (for waste rock and ore hauling) will be constructed of coarse gravel. During the dry season, chemical suppressants such as Coherex or magnesium chloride will be applied to reduce fugitive dust emissions. Based on guidance from the Colorado Department of Health (Tistinic 1985) and based on assumed BACT fugitive

dust reductions for other surface mining operations (Union Oil Company 1982; Galactic Resources 1985), the assumed reduction for chemical suppressants is 85 percent.

Uncontrolled Emissions:

The calculated emission factor is shown below.

$$\begin{aligned} E.F. &= (0.8)(5.9)(1.93/12)(19/30)(197/3)^{0.7}\,(6/4)^{0.5} \\ &= 11.0 \text{ lbs/vmt} \end{aligned}$$

where

$$\begin{aligned} \text{vmt/yr} &= (4.5 \text{ miles/RT})(26.28 \times 10^{6} \text{ tons/yr})/(164 \text{ tons/trips}) \\ &= 721{,}100 \end{aligned}$$

therefore

$$\begin{aligned} E &= (721{,}100 \text{ vmts/yr})(11.0 \text{ lbs/vmt})(1 \text{ tons/2000 lbs}) \\ &= \underline{905.6 \text{ lbs/hr}} \end{aligned}$$

Maximum 24-hr Emissions:

The Maximum 24-hr emissions are calculated by assuming an 85 percent reduction for application of chemical dust suppressants. The calculated values are indicated below.

$$\begin{aligned} E &= (905.6 \text{ lbs/hr})(1 - 0.85) \\ &= 135.8 \text{ lbs/hr} \end{aligned}$$

Annual Average Emissions:

The Annual Average emission rates are calculated by multiplying the Uncontrolled values by 0.0284 as described in Section 2.2.

$$\begin{aligned} E &= (905.6 \text{ lbs/hr})(8{,}760 \text{ hrs/yr})(0.0284)(1/2000) \\ &= 112.6 \text{ tons per year} \end{aligned}$$

Exhaust Emissions:

Personnel at the Cummins Engines Company were contacted for emission factors that would be appropriate for 170-ton trucks. The following information, based on the Federal EPA 13 mode cycle tests performed in December 1978, were provided:

Pollutant	Emission Factors
NO_x	7.63 g/hp-hr
HC	0.12 g/hp-hr
CO	1.09 g/hp-hr
PM	0.25 g/hp-hr

These should be applied for a weighted 8-hour day for the 1600-hp engine in a the 170-ton trucks.

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Applying these factors to sources at the Quartz Hill mine for a 1600 hp engine yields the following emissions (assuming 30 trucks/day, 8 hrs/day, and 320 days per year):

Pollutant	Emission Factor (lbs/hr/truck)	Emissions (tons/yr)
NO_x	26.89	1032.0
HC	0.42	16.1
CO	3.84	147.5
PM	0.88	33.8

These estimates are conservative (i.e., on the high side) since load factors were not applied for the 170-ton trucks as they are to be used in the mining operations proposed for the Quartz Hill mine. For example, the full 1600 hp would be used only during times when the truck is climbing an 8 percent grade.

2.4.5 Waste Rock Dumping

The uncontrolled emission factor for batch rock dumping is as follows (Colorado Dept. Health 1984, p. 41):

$$\text{E.F. (lbs/ton)} = k(0.0018)\frac{(S/5)(U/5)(H/5)}{(M/2)^2\ (Y/6)^{0.33}}$$

k = 30 um size parameter, 0.73
S = silt content, 0.25 percent
U = wind speed, assume 3.5 mph
H = drop height, assume 5 ft
M = moisture content, 4 percent
Y = truck size, 113 cu yd

$$\text{E.F.} = 0.73(0.0018)\frac{(0.25/5)(3.5/5)(5/5)}{(4/2)^2(113/6)^{0.33}}$$

$$= 4.4 \times 10^{-6} \text{ lbs/ton}$$

The Maximum 24-hour emission rate is:

72,000 tons/day (4.4×10^{-6} lbs/ton)(1/24)
= <u>0.32 lbs/hr</u>

The annual emission rate is:

0.32 lbs/hr (8,760 hrs/yr)(1/2000)
= <u>1.40 tons/yr</u>

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2.4.6 Waste Rock Stockpile Wind Erosion

The waste rock stockpile area will be roughly 300 ac by year 16 of operations. The emission factor for active storage areas is 0.072 lbs/ac/day, as calculated previously in Section 2.3.2. The Maximum 24-hour emissions are:

(0.072 lbs/ac/day)(300 ac)(1/24)
= 0.90 lbs/hr

The Annual Average emissions are calculated using a 0.345 penetration factor (see Section 2.2.4):

(0.90 lbs/yr)(8,760 hrs/yr)(0.345)(1/2000)
= 1.36 tons/yr

2.4.7 Ore Removal

The emission factor for ore removal is 7.1×10^{-6} lbs/ton, as calculated in Section 2.4.3. The Maximum 24-hour emissions are:

(80,000 tpd)(7.1×10^{-6} lbs/ton)(1/24)
= 0.024 lbs/hr

The Annual Average emissions are:

(0.024 lbs/hr)(8,760 hrs/yr)(1/2000)
= 0.10 tons/yr

2.4.8 Ore Haul Road

Ore will be hauled by 170-ton end dump trucks approximately 1.65 mi to the crusher. Each truck will average 164 tons of rock per trip. The haul road will be made of coarse gravel. Chemical dust suppressants will be applied as discussed in Section 2.2.2 to control fugitive dust emissions. Fugitive dust emissions for travel on the haul road are calculated from the equation presented in Section 2.4.4 and as indicated below.

$$E.F. = k(5.9)(s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5} = \text{lbs/vmt}$$

where
k = 0.8 size multiplier (30 um)
s = mean silt content, 1.93 percent
S = mean vehicle speed, 19 mph
W = mean vehicle weight (115 + 279)/2 = 197 tons
w = mean number of wheels, 6

Uncontrolled Emissions:

The calculated emission factor is shown below:

$$E.F. = (0.8)(5.9)(1.93/12)(19/30)(197/3)^{0.7}(6/4)^{0.5}$$
$$= 11.0 \text{ lbs/vmt}$$

$$\text{vmt/yr} = (3.3 \text{ miles/RT})(80{,}000 \text{ tons/day})(1 \text{ trip}/164 \text{ tons})(365 \text{ days/yr})$$
$$= 587{,}560$$

therefore

$$E = (587{,}560 \text{ vmt/yr})(11.0 \text{ lbs/vmt})(1 \text{ tons}/2000 \text{ lbs})$$
$$= \underline{3{,}230 \text{ tons/yr}}, \text{ or}$$
$$= \underline{737 \text{ lbs/hr}}$$

Maximum 24-hr Emissions:

The Maximum 24-hr emissions are calculated by multiplying the above Uncontrolled values by 0.15 to account for the 85 percent mitigation achieved by application of dust suppressants. The values are indicated below.

= 110.6 lbs/hr

Annual Average Emissions:

The Annual Average emission rates are calculated by multiplying the Uncontrolled value by the 0.0284 average penetration factor (see Section 2.2.2).

= 91.7 tons per year

Exhaust Emissions:

Exhaust emissions are calculated for the 170-ton truck from information presented in Section 2.4.4 using the following factors:

Pollutant	Emission Factors (lbs/hr/truck)
NO_x	26.89
HC	0.42
CO	3.84
PM	0.88

It is assumed that 30 trucks would be required for 8 hrs/day for 320 days/yr to haul the ore. As a result, the above emission factors are multiplied by (30 trucks/day)(8 hrs/truck)(320 days/yr)(1 tons/2000 lbs). The results are indicated below.

NO_x = 1,033 tons/yr
HC = 16 tons/yr
CO = 147 tons/yr
PM = 34 tons/yr

2.4.9 Primary Ore Crushing

Ore Dumping

The ore will be unloaded by end-dump trucks into the ore crusher hopper. The emission factor for batch rock dumping is as follows (Colorado Dept. Health 1984, p. 41):

$$\text{E.F. (lbs/ton)} = \frac{k(0.0018)(s/5)(u/5)(H/5)}{(M/2)^2(Y/6)^{0.33}}$$

k = 30 um size parameter, 0.73
s = silt content, 0.25 percent
u = wind speed, assume 1 mph
H = drop height, assume 30 ft
M = moisture content, 4 percent
Y = truck capacity, 113 cu yd

$$\text{E.F.} = \frac{0.73(0.0018)(0.25/5)(1/5)(30/5)}{(4/2)^2(113/6)^{0.33}}$$

$$= 7.4 \times 10^{-6} \text{ lbs/ton}$$

The average annual Uncontrolled emission rate is:

$(7.4 \times 10^{-6}$ lbs/ton)(80,000 tons/day)(365 days/yr)(1/2,000)
= 0.11 tons/yr

Primary Ore Crushing

The Uncontrolled emission factor for high moisture ore is 0.004 lbs/ton (Colorado Dept. Health 1984, p. 23). The annual average Uncontrolled emissions are:

0.004 lbs/ton (80,000 tons/day)(365 days/yr)(1/2,000)
= 58.4 tons/yr

Combined Controlled Emissions

A baghouse filter will be used to control emissions from the combined ore dumping and ore crushing operations. The uncontrolled emissions from the combined operation are 58.5 tons/yr. Assuming a 95 percent efficiency for the baghouse, the controlled emission rate is:

58.5 tons/yr (1-0.95)
= 2.93 tons/yr
= 0.67 lbs/hr

2.4.10 Petroleum Storage Tanks

Diesel Fuel Storage

Diesel fuel storage at the mine site will be in two 80,000 gallon capacity fixed roof tanks measuring 25 ft in diameter by 24 ft high. Average annual throughput will be 5.6 x 10^6 gallons. Hydrocarbon emissions from these tanks are calculated according to AP-42, Section 4.3, titled "Storage of Organic Liquids."

Breathing Losses:

$$L_B = 2.26 \times 10^{-2} M \left(\frac{P}{14.7-P}\right)^{0.68} D^{1.73} H^{0.51} T^{0.5} F_p \, C \, K_c$$

where:

L_B = Fixed roof breathing losses in lbs/yr
M = Molecular weight = 130 lbs/lb mole (No. 2 oil)
P = True vapor pressure = 0.0045 psia
D = Tank diameter = 25 ft
H = Average vapor space height = 4 ft
T = Average ambient diurnal temperature change = 16°F
F_p = Paint factor = 1.20 (specular aluminum)
C = Adjustment factor for small tanks = 0.97
K_c = Crude oil factor = 1.0

Inserting the above values into the equation results in calculated breathing losses of 29.65 lbs/year or as indicated below for both tanks.

= 59.3 lbs/yr, or
= 0.03 tons/yr

Working Losses:

$L_W = 2.40 \times 10^{-2} \, M \, P \, K_n \, K_c$ in lbs/10^3 gallon throughput

where

M = Molecular weight = 130 lbs/lb mole
P = True vapor pressure = 0.0045 psia
K_n = Turnover factor = 1.0
K_c = Crude oil factor = 1.0

Inserting the above values into the equation results in calculated working losses of 0.01404 lbs/1000 gallons. Total losses are calculated as follows:

$$\left(\frac{0.01404 \text{ lbs}}{1{,}000 \text{ gal}}\right)(35 \text{ turnovers/yr})(80{,}000 \text{ gals/turnover})(2 \text{ tanks})$$

= 78.6 lbs/yr, or
= 0.04 tons/yr

Unleaded Fuel Tank

Unleaded fuel will be stored at the mine site in one 12,000 gallon underground tank, with an approximate average throughput of 100,000 gals/yr. Breathing losses from this tank will be minor since it is buried. Working losses are calculated as previously indicated.

$L_W = 2.40 \times 10^{-2}\ M\ P\ K_n\ K_c$ lbs/10^3 gallon throughput

where

M = Molecular weight = 66 lbs/lb mole
P = True vapor pressure = 4.2 psia
K_n = Turnover factor = 1.0
K_c = Crude oil factor = 1.0

Inserting the above values into the equation results in calculated working losses, L_w, = 6.65 lbs/10^3 gallons throughput.

Total working losses are calculated as follows:

L_W = (6.65 lbs/1000 gal)(8.3 turnovers/yr)(12,000 gals/turnover)
= 662 lbs/yr, or
= 0.33 tons/yr

2.4.11 Residences and Other Building Heating

Employees will be housed in dorms at the mine site area and at the Tunnel Creek valley concentrator area. The residence facilities in the Tunnel Creek valley will be heated using the waste heat from the combined cycle gas turbine power plant. Therefore, no additional air pollutants will be emitted from these residence facilities.

There will be two areas at the mine site where space heating will not be provided by the power plant in the Tunnel Creek valley. Both the residence/dining room buildings in the Beaver Creek valley and the crusher/mine services buildings in the western part of the Quartz Hill basin will be heated by burning No. 2 fuel oil in small boilers. Each building will be heated by its own boiler. The emissions from each of these categories of sources is presented in Tables C-2-2 and C-2-3. The residence/dining hall building will be approximately 1.2 mi northwest of the mine services buildings and about 1.4 mi north-northwest of the crusher building. The emissions were calculated from AP-42, Table 1.3.1.

2.4.12 Mine Access Road

The mine access road will be used to carry workers and supplies to the worker housing area and the mine service area. The access road will be 19.6 mi round trip and will be unpaved. Estimated vehicle travel along the road will be as follows (U.S. Borax 1986b):

18-wheel tractor trailer - 2 round trips/day
6-wheel flat bed truck - 2 round trips/day
6-wheel bus - 2 round trips/day
Pickup trucks - 20 round trips/day

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TABLE C-2-2

ANNUAL EMISSIONS FROM RESIDENCES/DINING ROOM BUILDINGS
DUE TO SPACE HEATING USING NO. 2 FUEL OIL

Pollutant	Emission Factor (lbs/10^3 gal)1/	Emissions (lbs/hr)2/	Emissions (tons/yr)2/
Particulate	2	0.1	0.2
SO_2	142 S (S=0.05 percent)	0.2	0.9
CO	5	0.1	0.6
HC	1	0.03	0.1
NO_x	22	0.6	2.8

1/ Emissions factors for industrial/commercial boilers are used. Total fuel consumption is 254,000 gals/yr.

2/ A total of 8,760 hours per year is assumed.

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TABLE C-2-3

ANNUAL EMISSIONS FROM THE CRUSHER/MINE SERVICES BUILDINGS
DUE TO SPACE HEATING USING NO. 2 FUEL OIL

Pollutant	Emission Factor (lbs/10^3 gal)1/	Emissions (lbs/hr)2/	Emissions (tons/yr)2/
Particulate	2	0.1	0.6
SO_2	142 S (S=0.05 percent)	0.5	2.2
CO	5	0.4	1.6
HC	1	0.1	0.3
NO_x	22	1.6	6.9

1/ Emissions factors for industrial/commercial boilers are used. Total fuel consumption is 626,000 gals/yr.

2/ A total of 8,760 hours per year is assumed.

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The same road material (1.93 percent silt) will be used to construct the mine access road and the mine haul roads. Fugitive dust emissions for travel in the unpaved road are calculated using the equations presented in Section 2.4.4 and are indicated below:

<u>18-Wheel Tractor Trailer</u>

$$E.F. = K\ (5.9)(s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5}\ \text{lbs/vmt}$$

K = 0.8 size multiplier
s = 1.93 percent silt
S = 25 mph vehicle speed
W = 42.5 ton vehicle weight
w = 18 wheels

$$E.F. = 0.8(5.9)(1.93/12)(25/30)(42.5/3)^{0.7}(19/4)^{0.5}$$
$$= 8.97\ \text{lbs/vmt (uncontrolled)}$$

The Uncontrolled hourly emissions are as follows:

(8.97 lbs/vmt)(2 trips/day)(19.6 mi/trip)(1/24) = 14.7 lbs/hr

Assuming an 85 percent dust reduction by application of penetrating chemicals, the controlled emissions are:

(14.7 lbs/hr)(1 - 0.85) = 2.20 lbs/hr

Using a 0.0284 annual penetration factor (Section 2.2.2), the annual emission rate is:

(14.7 lbs/hr)(0.0284)(8.760 hr/yr)(1/2000) = 1.82 tons/yr

<u>6-Wheel Flat Bed Trucks</u>

Uncontrolled $E.F. = k(5.9)(s/12)(S/30)(W/3)^{0.7}(W/4)^{0.5}$ lb/vmt

s = 1.93 percent
S = 25 mph
W = 10 tons
w = 6 wheels

Uncontrolled Emission Factor =

$$(0.8)(5.9)(25/30)(1.93/12)(10/3)^{0.7}(6/4)^{0.5}$$
$$= 2.02\ \text{lbs/vmt}$$

Assuming an 85 percent dust reduction by application of chemical suppressants, the worst case 24-hr emissions are:

(2.02 lbs/vmt)(2 trips/day)(19.6 mi/trip)(1-0.85)(1/24)
= 0.50 lbs/hr

Assuming a 0.0284 annual penetration factor (Section 2.2.2), the annual emissions are:"

(2.02 lbs/vmt (39.2 mi/day)(365 days/yr)(0.0284)(1/2000)
= 0.41 ton/yr

<u>6-Wheel Bus</u>

Uncontrolled E.F. = $k(5.9)(s/12)(S/30)(W/3)^{0.7}(s/4)^{0.5}$ lbs/vmt

K = 0.8 multiplier (30 microns)
s = 1.93 percent silt
S = 25 mph
W = 10 tons
w = 6 wheel

E.F. = $0.8(5.9)(1.93/12)(25/30)(10/3)^{0.7}(6/4)^{0.5}$
= 2.02 lbs/vmt

Assuming 85 percent reduction by chemical suppressants, the worst case 24-hour emissions are:

(2.02 lbs/vmt)(39.2 mi/day)(1-0.85)(1/24)
= 0.50 lbs/hr

Assuming a 0.0284 annual penetration factor (Section 2.2.2), the annual dust emissions are:

(2.02 lbs/vmt)(39.2 mi/day)(365 day/yr)(0.0284)(1/2000)
= 0.41 tons/yr

<u>Pickup Trucks</u>

The Uncontrolled fugitive dust emission factor:

E.F. = $k(5.9)(s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5}$ lbs/vmt

k = 0.8 size factor (30 microns)
s = 1.93 percent silt
S = 25 mph
W = 2 tons
w = 4 wheels

E.F. = $(0.8)(5.9)(1.93/12)(25/30)(2/3)^{0.7}(4/4)^{0.5}$ lbs/vmt
= 0.54 lbs/vmt

Assuming an 85 percent dust reduction by chemical suppressants, the Maximum 24-hr emissions are:

(0.54 lbs/vmt)(293 mi/day)(1-0.85)(1/24)
= 1.31 lbs/hr

Assuming a 0.0284 annual penetration factor (Section 2.2.2) the annual dust emissions are:

(0.54 lbs/vmt)(392 mi/day)(365 day/yr)(0.0284)(1/2000)
= 1.09 tons/yr

Tailpipe Emissions

The tailpipe emissions per vehicle mile traveled will be similar for vehicles along the mine access road and the Tunnel Creek access road. For the mine access road, the tailpipe emissions were calculated by multiplying the Tunnel Creek access road emissions by the ratio of the vehicle miles traveled at the two sites. The calculated tailpipe emissions along the mine access road are summarized below:

	Tractor Trailer	Flat Bed Trucks	Buses	Pickups	Total
NO_x (tons/yr)	0.15	0.02	0.02	0.22	0.41
Hydrocarbons (tons/yr)	0.07	0.01	0.01	0.20	0.29
CO (ton/yr)	0.29	0.05	0.05	2.5	2.88
PM (ton/yr)	-	-	-	0.07	0.07

2.5 WILSON ARM WHARF SOURCES

The only source of air pollutants at the Wilson Arm wharf are those from fuel storage tanks and sea-going vessels and aircraft.

2.5.1 Fuel Storage Tanks

Fuel storage tanks include those for the power plant fuel oil, diesel fuel, and unleaded gas. These tanks are essentially the same as those located in the Tunnel Creek valley and at the mine site. Their emissions are as follows.

Power Plant Fuel Storage

Fuel oil for the power plant will be received in a single 54,000 barrel fixed roof tank, identical to those in the Tunnel Creek valley. However, the throughput will be twice that for each tank at Tunnel Creek. Based on the calculations for the Tunnel Creek valley tanks, the breathing losses and working losses are indicated below for No. 2 fuel oil:

Breathing Losses:

= 400 lbs/yr, or
= 0.2 tons/yr

Working Losses:

(0.01404 lbs/1000 gal)(20 turnovers/yr)(2.3 x 10^6 gals/turnover)

= 0.32 tons/yr, or
= 0.07 lbs/hr

Diesel Fuel Storage

Diesel fuel will be stored in a single 20,000 barrel fixed roof tank identical to the one at the Tunnel Creek valley. The breathing losses for this tank are 0.08 tons per year (0.02 lbs/hr) and the working losses are 0.07 tons per year (0.02 lbs/hr).

Unleaded Fuel Tank

Unleaded fuel will be stored in a single 12,000 gallon underground tank identical to the one at the mine site. Breathing losses from this tank are negligible because it is buried. Working losses are 0.33 tons per year (0.08 lbs/hr).

2.5.2 Sea-Going Vessels and Aircraft

The following means of transportation will be considered as Wilson Arm wharf sources. Tractor trailer, bus, and pickup trucks have been accounted for in the Tunnel Creek area and are not considered here.

1 ea. Monohull Crew Boat ferrying up to 150 passengers/trip
1 ea. 3000 dwt barge with 1 tug
35,000 dwt tankers
Planes
Helicopters

Monohull Crew Boat

Propulsion engines, 2 ea., 1200 BHP; 110 gal diesel consumed/hour, 1 way trip between Ketchikan and the wharf will take 2.5 hours. The annual fuel consumption is calculated below based on eight trips/week.

(8 trips/week)(2.5 hrs/trip)(110 gals/hr)(52 weeks/yr)
= 114.4 x 10^3 gals/yr

Using the emission factors presented for coastal class vessels as presented in AP-42, Table 3.2.3-1, emission estimates by pollutant are calculated below:

Pollutant	Emission Factor (lbs/10^3 gal)	Emissions (tons/yr)
PM	110	6.2
SO_x (as SO_2)	27	1.5
CO	100	5.7
HC	50	2.9
NO_x	280	16.0

Plane (assume a Dehavilland Beaver)

The Dehavilland Beaver consumes 23 gals/hr at cruising speed and about the same for takeoff and landing. The fuel consumption rate indicated in AP-42, Table 3.2.1-7 suggests that the Piper Warrior uses about the same amount of fuel as a Beaver would use. Assuming emissions are similar to a Piper Warrior, the landing/takeoff cycle emissions would be (AP-42, Table 3.2.1-9) as calculated below. The emissions based on one trip per day are listed below.

Pollutant	Emissions/cycle (lb)	(Tons/yr)
CO	14.37	2.62
NO_x	0.02	0.01
HC	0.26	0.05

Helicopter (assume a Bell Jet Ranger)

The Bell Jet Ranger commercial helicopter consumes 25 gals/hr at cruising speed and at takeoff. Assuming emissions are about 25 percent of those of a Huey (AP-42, Table 3.2.1-8), based on fuel consumption during takeoffs, the emissions per year are as follows assuming one trip/day:

Pollutant	Emission/Takeoff or Approach (lb)	(Tons/yr)
CO	0.4	0.15
NO_x	0.3	0.11
Total HC	0.6	0.22
SO_x	0.05	0.02

Sea-Going Barge (2,500 hp tug)

A typical commercial barge (sea-going) with a 2,500 hp tug consumes 2,300 gals fuel/day at full load. Assuming it takes about one hour under 1/4 to 1/2 power to come into the wharf area, taking account of the incoming and outgoing portions of each trip, approximately 2,600 gallons of diesel will be burned per year by the tug in the immediate vicinity of the wharf. Approximately 48 gals/hr of fuel will be used entering and leaving the facility. Applying emission factors from AP-42, Table 3.2.3-3, for a 2500 hp tug, emissions are calculated below:

Pollutant	Emission Factor (lbs/10^3 gal)	Emissions (tons/yr)	Emissions (lbs/hr)
PM	110	0.15	5.3
SO_2	41	0.05	2.0
CO	59.8	0.08	2.9
HC	22.6	0.03	1.1
NO_x	419.6	0.54	20.2

Local Barge/Tug (assume 900 hp)

A commercial harbor tug consumes 700 gals/day of fuel during its operations. Assuming it takes about one hour under 2/3 power to come into the wharf area, about 30 gallons diesel fuel is burned. For 20 trips per year from Grays Harbor to Quartz Hill, taking account of the incoming and outgoing portions of each trip, approximately 1200 gallons of diesel will be burned per year by local tugs in the immediate vicinity of the wharf. Applying emission factors from Table 3.2.3-3 in AP-42, emissions for this source are calculated below:

Pollutant	Emission Factor (lbs/10^3 gal)	Emissions (tons/yr)	Emissions (lbs/hr)
PM	110	0.07	3.3
SO_2	41	0.03	1.2
CO	62.2	0.04	1.9
HC	16.8	0.01	0.5
NO_x	167.2	0.10	5.0

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35,000 dwt Tanker

An oil company that operates a 35,000 dwt oil tanker indicates the following fuel burning rates:

37 tons/day diesel	(10,150 gals/day) at 80 percent power
3 tons/day diesel	(820 gals/day) under housekeeping mode
13 tons/day diesel	(3,560 gals/day under housekeeping and pumping mode

The schedule calls for 10 deliveries of approximately 4,660,000 gallons per trip of No. 2 type fuel oil and 1,100,000 gallons per trip of diesel oil to the Quartz Hill project.

It will take about 12 hours to unload the diesel oil to the storage tanks and about 8 hours to unload the No. 2 fuel oil to the storage tanks. Assuming the operations occur simultaneously, it will take about 1/2 day to unload the tanker. Allowing for setting up and disconnecting the lines and for other miscellaneous activities, it is herein assumed that the tanker will be at the wharf in a housekeeping mode for an additional 12 hours. These activities will consume approximately 2,190 gallons diesel fuel/trip or 21,900 gallons diesel fuel per year by the tankers.

It will take one hour each to come into and leave the wharf area. This will consume 845 gallons per trip or 8,460 gallons/year. Assuming the emissions from a 35,000 dwt tanker are similar to those from 15,000 dwt and 25,000 dwt, Table A-6, titled "Fuel Consumption Rates and Emission Factors for Marine Tankers" (from A Handbook for Estimating the Potential Air Quality Impacts Associated with Oil and Gas Development Offshore prepared for DOI 1983) are applied for the burning of a diesel oil. Emissions of the housekeeping/pumping mode and cruise mode are calculated by multiplying the respective fuel consumption rate described above and dividing by 1 tons/2000 lbs, are as follows:

Housekeeping/Pumping Mode

Pollutant	Emission Factor (lbs/10^3 gal)	Emissions (tons/yr)	Emissions (lbs/hr)
Particulates	19.05	0.21	1.7
SO_2	80 (S=0.5 percent)	0.87	7.4
CO	0.6	0.01	0.1
HC	2.94	0.03	0.3
NO_x	35.6 (avg.)	0.39	4.6

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Cruise Mode

Pollutant	Emission Factor ($lbs/10^3$ gal)	Emissions (tons/yr)	Emissions (lbs/hr)
Particulates	19.05	0.08	16
SO_2	80 (S=0.5 percent)	0.34	68
CO	0.6	0.01	0.5
HC	2.94	0.01	2.5
NO_x	50.24	0.21	42

2.6 TAILINGS DISPOSAL POND DAM CONSTRUCTION EMISSIONS

One of the project alternatives includes disposing of the tailings into disposal ponds formed by constructing rockfill dams at Tunnel Creek and Aronitz Creek. The Tunnel Creek dam would be constructed of waste rock material, with a total rock quantity of 196,000,000 tons. Assuming the dam will take 20 years to construct, the daily rockfill placement would be 26,800 tons/day. The waste rock would be hauled in 170 ton trucks, using chemically treated gravel haul roads.

2.6.1 Haul Road Fugitive Dust

The haul distance near the dam is roughly five miles round trip. The uncontrolled emission factor is 36.1 lbs/vmt, and the assumed dust reduction by chemical sprays is 85 percent (see Section 2.4.4).

Uncontrolled Emissions:

$$\text{vmt/day} = 26{,}800\ \frac{\text{tons}}{\text{day}} \times \frac{1\ \text{trip}}{164\ \text{trips}} \times \frac{5\ \text{mi}}{\text{trip}} = 817\ \text{vmt/day}$$

$$E = 36.1\ \frac{\text{lbs}}{\text{vmt}} \times 817\ \frac{\text{vmt}}{\text{day}} \times \frac{1\ \text{day}}{24\ \text{hrs}} = 1{,}228\ \text{lbs/hr}$$

$$E = 1{,}228\ \frac{\text{lbs}}{\text{hr}} \times (1-0.85)$$

$$= 184\ \text{lbs/hr}$$

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2.6.2 Rockfill Dumping and Placement

The assumed emission factors for rockfill dumping and placement are 0.01 lbs/ton for each operation. This emission factor assumes that the rockfill contains more than 4 percent water. The combined emission factor for the dumping/placement operations is 0.02 lbs/ton.

$$E = 26{,}800 \ \frac{\text{tons}}{\text{day}} \times 0.02 \ \frac{\text{lbs}}{\text{ton}} \times \frac{1 \text{ day}}{24 \text{ hrs}}$$

$$= 22.3 \text{ lbs/hr}$$

That emission rate applies to the highest 24-hour average, on a dry day on which no mitigation can be used.

2.7 SUMMARY OF CALCULATED EMISSION RATES

The calculated emission rates for all operations at Tunnel Creek, the mine site, and the Wilson Arm wharf are listed in Table C-2-4. The "Maximum 24-Hr" value listed in that table would apply to emissions on a dry day during which natural fugitive dust reductions due to rainfall would not occur.

TABLE C-2-4

SUMMARY OF EMISSIONS

80,000 TPD FACILITY

Operations	Uncontrolled (lbs/hr)	Maximum 24-hr (lbs/hr)	Annual Average (tons/yr)
Tunnel Creek Valley			
Power Plant			
PM	N/A	3.6	13.7
SO_2	N/A	31	134
NO_x	N/A	217	955
CO	N/A	67	294
VOC	N/A	24	107
Coarse Ore Stockpile			
Load-in by Conveyor Transfer Point	0.16	0.05	0.21
Wind Erosion	0.1	0.01	0.02
Load-out from Coarse Ore Stockpile	N/A	0.01	0.03
Petroleum Storage Tanks			
Power Plant Fuel			
Breathing Losses	N/A	0.1	0.3
Working Losses	N/A	0.1	0.3
Diesel Fuel Storage			
Breathing Losses	N/A	Neg.	0.1
Working Losses	N/A	Neg.	0.1
Concentrator Access Road			
Fugitive Dust	N/A	0.7	0.3
Tailpipe Emissions			
CO	N/A	0.4	1.8
NO_x	N/A	0.1	0.3
PM	N/A	Neg.	0.1
VOC	N/A	0.1	0.2
Mining Operation Sources			
Drilling of Ore and Waste Rock	0.7	0.5	2.2

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TABLE C-2-4 (Continued)
SUMMARY OF EMISSIONS
80,000 TPD FACILITY

Operations	Uncontrolled (lbs/hr)	Maximum 24-hr (lbs/hr)	Annual Average (tons/yr)
Mining Operations (Continued)			
Blasting of Ore and Waste Rock	8.5	8.5	37.2
Waste Rock Removal	0.1	0.1	0.1
Waste Rock Haul Road			
Fugitive Dust	905.6	135.8	112.6
Tailpipe Emissions			
NO_x	N/A	806.7	1,032.0
HC	N/A	12.6	16.1
CO	N/A	115.2	147.5
PM	N/A	26.4	33.8
Waste Rock Dumping	0.3	0.3	1.4
Waste Rock Stockpile Wind Erosion	0.9	0.9	1.4
Ore Removal	0.1	0.1	0.1
Ore Haul Road			
Fugitive Dust	737	110.6	91.7
Tailpipe Emissions			
NO_x	N/A	806.7	1,033.0
HC	N/A	12.6	16.0
CO	N/A	115.2	147.0
PM	N/A	26.4	34.0
Primary Crushing of Ore	N/A	0.7	2.9
Petroleum Storage			
Diesel Fuel			
Breathing Losses	N/A	Neg.	Neg.
Working Losses	N/A	Neg.	Neg.
Unleaded Fuel			
Breathing Losses	N/A	Neg.	Neg.
Working Losses	N/A	Neg.	0.3

TABLE C-2-4 (Continued)
SUMMARY OF EMISSIONS
80,000 TPD FACILITY

Operations	Uncontrolled (lbs/hr)	Maximum 24-hr (lbs/hr)	Annual Average (tons/yr)
Residence/Dining Buildings			
PM	N/A	0.1	0.2
SO_2	N/A	0.2	0.9
CO	N/A	0.1	0.6
HC	N/A	Neg.	0.1
NO_x	N/A	0.6	2.8
Crusher/Mine Service Building			
PM	N/A	0.1	0.6
SO_2	N/A	0.5	2.2
CO	N/A	0.4	1.6
HC	N/A	0.1	0.3
NO_x	N/A	1.6	6.9
Mine Access Road			
Fugitive Dust	N/A	4.51	3.74
Tailpipe Emissions			
CO	N/A	0.66	2.88
NO_x	N/A	0.09	0.41
PM	N/A	0.02	0.07
VOC	N/A	0.07	0.29
Wilson Area Wharf			
Power Plant Fuel Storage			
Breathing Losses	N/A	Neg.	0.2
Working Losses	N/A	0.1	0.3
Diesel Fuel Storage			
Breathing Losses	N/A	Neg.	0.1
Working Losses	N/A	Neg.	0.1
Unleaded Fuel			
Breathing Losses	N/A	Neg.	Neg.
Working Losses	N/A	0.1	0.3
Planes and Helicopters			
SO_2	N/A	0.1	0.02
PM	N/A	-	-
CO	N/A	0.6	2.7
HC	N/A	0.1	0.3
NO_x	N/A	0.1	0.1

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TABLE C-2-4 (Continued)

SUMMARY OF EMISSIONS

80,000 TPD FACILITY

Operations	Uncontrolled (lbs/hr)	Maximum 24-hr (lbs/hr)	Annual Average (tons/yr)
Tugboats (20 trips/yr)			
SO_2	N/A	0.4	0.1
PM	N/A	0.8	0.2
CO	N/A	0.4	0.1
HC	N/A	0.4	0.1
NO_x	N/A	2.1	0.5
35,000 dwt Tanker (10 trips/yr)			
SO_2	N/A	68	1.2
PM	N/A	16	0.3
CO	N/A	0.5	0.1
HC	N/A	2.5	0.1
NO_x	N/A	42	0.6

3.0 METEOROLOGY

3.1 STATION DESCRIPTIONS

Two station-years of meteorological data collected by the Quartz Hill and Tunnel Creek monitoring stations have been compiled into a form compatible with air quality dispersion models. An inventory of data used from the two study stations is presented in Table C-3-1. The data received from U.S. Borax consisted of temperature, wind direction, wind speed, and stability class.

The meteorological stations were located in the vicinity of the Quartz Hill mine area and in the Tunnel Creek valley. The Quartz Hill station consisted of a 150-ft tower located at the north end of the proposed mine area in a saddle separating the White Creek and Beaver Creek drainage areas. The base elevation of the tower is 1,925 ft (U.S. Borax 1983). The 30-ft sensor level was used for the analysis. Terrain to the north of the Quartz Hill station rises to 3,500 ft.

Two meteorological stations were operated in the vicinity of the proposed Tunnel Creek power plant. A mechanical weather station served as the prime data source. Terrain surrounding the Tunnel Creek site rises to elevations in excess of 4,000 ft.

3.2 MEASURED METEOROLOGICAL CONDITIONS

Distributions of temperature, wind direction, wind speed, and stability class have been produced to characterize the meteorological conditions at Quartz Hill and Tunnel Creek. Annual wind rose tables for Quartz Hill and Tunnel Creek are presented in Tables C-3-2 and C-3-3, respectively. Stability wind rose tables (joint frequency distributions of wind direction, wind speed, and stability class) are presented in Tables C-3-4 to C-3-9 for Quartz Hill and Tables C-3-10 to C-3-15 for Tunnel Creek. In addition, monthly averages and ranges of temperature and wind speed are presented in Table C-3-16 for the Quartz Hill station and in Table C-3-17 for the Tunnel Creek station.

Predicted air concentrations are inversely proportional to wind speed. Concentrations become unrealistically large when wind speeds less than 1 mps are input into the air quality models. Therefore, special consideration is given to calms. Calms are defined as an hourly wind speed of less than or equal to 1 mps and a wind direction the same as the previous hour (EPA 1984a, p. 1-1). For computer modeling purposes, calm hours were excluded from the calculations in accordance with the federal air quality modeling guidelines (EPA 1984b). Note that the joint frequency tables included calms in the 0-1 mps speed category without regard to directional persistence.

TABLE C-3-1

QUARTZ HILL AND TUNNEL CREEK METEOROLOGICAL DATA
PERIOD OF RECORD AND PERCENT DATA RECOVERY

	Quartz Hill	Tunnel Creek
Starting Date	9/1/81	5/16/83
Ending Date	8/31/82	5/15/84
Data Recovery (percent)		
Temperature	96.9	98.6
Wind Direction	95.8	92.2
Wind Speed	90.9	92.3
Stability	92.4	91.8
Percentage of Hours When All Four Parameters Are Valid	89.2	89.1

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Table C-3-2

U S Borax

Quartz Hill Molybdenum Project Mine Development

Quartz Hill Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

7900 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	7.14	1.41	0.18	0.10	0.01	0.00	0.00	0.00	8.84	0.76
NNE	3.71	2.13	0.19	0.04	0.00	0.00	0.00	0.00	6.06	1.00
NE	2.63	5.10	0.48	0.11	0.00	0.00	0.00	0.00	8.33	1.56
ENE	2.42	7.06	3.95	1.09	0.27	0.04	0.00	0.00	14.82	2.68
E	2.35	3.09	1.92	0.67	0.06	0.00	0.00	0.00	8.10	2.35
ESE	1.08	0.67	0.13	0.00	0.00	0.00	0.00	0.00	1.87	1.19
SE	0.84	0.66	0.04	0.03	0.00	0.00	0.00	0.00	1.56	1.13
SSE	0.96	0.72	0.06	0.01	0.00	0.00	0.00	0.00	1.76	1.04
S	2.16	1.18	0.06	0.01	0.00	0.00	0.00	0.00	3.42	0.97
SSW	1.82	2.28	0.15	0.01	0.00	0.00	0.00	0.00	4.27	1.28
SW	2.25	4.65	1.23	0.01	0.00	0.00	0.00	0.00	8.14	1.83
WSW	2.53	3.66	1.08	0.32	0.00	0.00	0.00	0.00	7.58	1.88
W	4.11	3.34	0.53	0.10	0.00	0.00	0.00	0.00	8.09	1.21
WNW	3.53	1.19	0.08	0.01	0.00	0.00	0.00	0.00	4.81	0.73
NW	4.80	0.90	0.11	0.05	0.01	0.00	0.00	0.00	5.87	0.76
NNW	5.75	0.68	0.05	0.00	0.00	0.00	0.00	0.00	6.48	0.62
TOTAL	48.09	38.71	10.24	2.57	0.35	0.04	0.00	0.00	100.00	1.50

Table C-3-3

U S Borax

Quartz Hill Molybdenum Project Mine Development

Tunnel Creek Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

7835 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	4.31	1.38	0.06	0.00	0.00	0.00	0.00	0.00	5.76	0.85
NNE	2.26	1.43	0.05	0.01	0.00	0.01	0.00	0.00	3.77	1.02
NE	2.02	1.24	0.34	0.03	0.01	0.00	0.00	0.00	3.64	1.35
ENE	6.33	3.83	0.11	0.01	0.03	0.00	0.00	0.00	10.31	1.01
E	7.20	13.68	0.11	0.01	0.00	0.00	0.00	0.00	21.01	1.18
ESE	1.39	1.21	0.05	0.00	0.00	0.00	0.00	0.00	2.65	1.08
SE	1.35	0.73	0.03	0.00	0.01	0.00	0.00	0.00	2.12	0.95
SSE	1.40	0.92	0.01	0.00	0.00	0.00	0.00	0.00	2.34	1.03
S	3.19	1.06	0.00	0.00	0.00	0.00	0.00	0.00	4.25	0.81
SSW	2.40	1.00	0.04	0.01	0.00	0.00	0.00	0.00	3.45	0.87
SW	2.80	0.97	0.01	0.00	0.00	0.00	0.00	0.00	3.78	0.84
WSW	3.94	1.71	0.08	0.00	0.00	0.00	0.00	0.00	5.73	0.90
W	7.53	5.53	0.28	0.00	0.00	0.00	0.00	0.00	13.34	1.11
WNW	4.71	3.05	0.93	0.01	0.00	0.00	0.00	0.00	8.70	1.36
NW	4.06	1.60	0.11	0.00	0.00	0.00	0.00	0.00	5.77	0.94
NNW	2.49	0.84	0.06	0.00	0.00	0.00	0.00	0.00	3.40	0.87
TOTAL	57.38	40.17	2.30	0.09	0.05	0.01	0.00	0.00	100.00	1.06

Table C-3-4
U S Borax

Quartz Hill Molybdenum Project Mine Development

Quartz Hill Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS A

625 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	0.64	1.44	0.00	0.00	0.00	0.00	0.00	0.00	2.08	1.45
NNE	0.16	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.64	1.52
NE	0.00	0.32	0.16	0.00	0.00	0.00	0.00	0.00	0.48	2.41
ENE	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.32	1.74
E	0.48	0.80	0.16	0.00	0.00	0.00	0.00	0.00	1.44	1.82
ESE	0.48	1.60	0.00	0.00	0.00	0.00	0.00	0.00	2.08	1.53
SE	0.80	2.24	0.00	0.00	0.00	0.00	0.00	0.00	3.04	1.19
SSE	0.64	2.56	0.16	0.00	0.00	0.00	0.00	0.00	3.36	1.40
S	3.20	5.12	0.00	0.00	0.00	0.00	0.00	0.00	8.32	1.27
SSW	3.20	5.76	0.00	0.00	0.00	0.00	0.00	0.00	8.96	1.17
SW	3.04	13.12	1.44	0.00	0.00	0.00	0.00	0.00	17.60	1.80
WSW	3.52	18.72	1.12	0.00	0.00	0.00	0.00	0.00	23.36	1.85
W	4.96	13.44	0.32	0.00	0.00	0.00	0.00	0.00	18.72	1.46
WNW	1.44	3.04	0.48	0.00	0.00	0.00	0.00	0.00	4.96	1.47
NW	1.76	2.08	0.00	0.00	0.00	0.00	0.00	0.00	3.84	1.10
NNW	0.16	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.80	1.25
TOTAL	24.48	71.68	3.84	0.00	0.00	0.00	0.00	0.00	100.00	1.55

Table C-3-5
U S Borax

Quartz Hill Molybdenum Project Mine Development

Quartz Hill Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS B

725 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	1.93	1.24	0.28	0.00	0.00	0.00	0.00	0.00	3.45	1.04
NNE	1.10	0.55	0.41	0.14	0.00	0.00	0.00	0.00	2.21	1.87
NE	0.69	0.28	0.14	0.00	0.00	0.00	0.00	0.00	1.10	1.14
ENE	0.41	1.24	0.14	0.00	0.00	0.00	0.00	0.00	1.79	1.83
E	1.52	1.66	0.55	0.00	0.00	0.00	0.00	0.00	3.72	1.46
ESE	1.24	1.93	0.14	0.00	0.00	0.00	0.00	0.00	3.31	1.32
SE	1.24	2.34	0.00	0.00	0.00	0.00	0.00	0.00	3.59	1.25
SSE	1.10	1.93	0.14	0.00	0.00	0.00	0.00	0.00	3.17	1.29
S	3.31	3.45	0.14	0.00	0.00	0.00	0.00	0.00	6.90	1.04
SSW	4.41	7.03	0.28	0.14	0.00	0.00	0.00	0.00	11.86	1.38
SW	4.28	15.31	5.24	0.00	0.00	0.00	0.00	0.00	24.83	2.09
WSW	2.21	10.48	2.48	0.28	0.00	0.00	0.00	0.00	15.45	2.12
W	3.45	5.24	0.41	0.14	0.00	0.00	0.00	0.00	9.24	1.38
WNW	1.93	1.52	0.00	0.00	0.00	0.00	0.00	0.00	3.45	0.92
NW	2.48	1.10	0.00	0.14	0.00	0.00	0.00	0.00	3.72	1.07
NNW	1.38	0.69	0.14	0.00	0.00	0.00	0.00	0.00	2.21	1.10
TOTAL	32.69	56.00	10.48	0.83	0.00	0.00	0.00	0.00	100.00	1.61

Table C-3-6
U S Borax

Quartz Hill Molybdenum Project Mine Development

Quartz Hill Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS C

947 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	3.59	0.84	0.21	0.21	0.00	0.00	0.00	0.00	4.86	1.00
NNE	2.43	0.95	0.42	0.00	0.00	0.00	0.00	0.00	3.80	0.97
NE	1.48	1.16	0.21	0.32	0.00	0.00	0.00	0.00	3.17	1.63
ENE	1.37	3.17	2.53	0.42	0.00	0.00	0.00	0.00	7.50	2.55
E	3.27	3.80	1.48	0.11	0.21	0.00	0.00	0.00	8.87	1.81
ESE	2.64	1.16	0.42	0.00	0.00	0.00	0.00	0.00	4.22	1.22
SE	1.69	1.48	0.11	0.11	0.00	0.00	0.00	0.00	3.38	1.29
SSE	2.32	1.48	0.21	0.00	0.00	0.00	0.00	0.00	4.01	0.98
S	5.91	2.22	0.11	0.11	0.00	0.00	0.00	0.00	8.34	0.90
SSW	3.17	4.96	0.00	0.00	0.00	0.00	0.00	0.00	8.13	1.28
SW	2.64	11.40	3.17	0.00	0.00	0.00	0.00	0.00	17.21	2.12
WSW	2.53	3.48	1.69	0.42	0.00	0.00	0.00	0.00	8.13	2.11
W	3.91	2.75	0.32	0.21	0.00	0.00	0.00	0.00	7.18	1.17
WNW	2.11	0.95	0.21	0.11	0.00	0.00	0.00	0.00	3.38	1.24
NW	2.53	0.74	0.11	0.11	0.11	0.00	0.00	0.00	3.59	1.19
NNW	3.91	0.32	0.00	0.00	0.00	0.00	0.00	0.00	4.22	0.64
TOTAL	45.51	40.87	11.19	2.11	0.32	0.00	0.00	0.00	100.00	1.53

Table C-3-7
U S Borax

Quartz Hill Molybdenum Project Mine Development

Quartz Hill Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS D

2943 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	7.65	0.88	0.31	0.20	0.03	0.00	0.00	0.00	9.07	0.80
NNE	4.01	2.65	0.24	0.07	0.00	0.00	0.00	0.00	6.97	1.02
NE	2.79	9.31	0.85	0.14	0.00	0.00	0.00	0.00	13.08	1.69
ENE	2.48	12.03	9.31	2.75	0.71	0.10	0.00	0.00	27.39	3.13
E	2.07	4.72	4.21	1.77	0.10	0.00	0.00	0.00	12.88	2.98
ESE	0.85	0.44	0.17	0.00	0.00	0.00	0.00	0.00	1.46	1.27
SE	0.75	0.10	0.07	0.03	0.00	0.00	0.00	0.00	0.95	1.11
SSE	0.61	0.20	0.03	0.03	0.00	0.00	0.00	0.00	0.88	1.02
S	1.12	0.14	0.03	0.00	0.00	0.00	0.00	0.00	1.29	0.71
SSW	0.75	0.95	0.27	0.00	0.00	0.00	0.00	0.00	1.97	1.62
SW	0.88	1.33	0.44	0.03	0.00	0.00	0.00	0.00	2.68	1.83
WSW	1.39	0.54	1.16	0.58	0.00	0.00	0.00	0.00	3.67	2.60
W	2.41	0.58	0.54	0.17	0.00	0.00	0.00	0.00	3.70	1.28
WNW	3.02	0.41	0.00	0.00	0.00	0.00	0.00	0.00	3.43	0.48
NW	4.21	0.20	0.20	0.07	0.00	0.00	0.00	0.00	4.69	0.68
NNW	5.57	0.24	0.07	0.00	0.00	0.00	0.00	0.00	5.88	0.57
TOTAL	40.57	34.73	17.91	5.84	0.85	0.10	0.00	0.00	100.00	1.96

Table C-3-8
U S Borax

Quartz Hill Molybdenum Project Mine Development

Quartz Hill Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS E

1666 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	12.67	1.80	0.06	0.00	0.00	0.00	0.00	0.00	14.53	0.61
NNE	6.48	3.00	0.06	0.00	0.00	0.00	0.00	0.00	9.54	0.89
NE	4.38	4.86	0.12	0.00	0.00	0.00	0.00	0.00	9.36	1.27
ENE	3.96	7.08	0.48	0.06	0.00	0.00	0.00	0.00	11.58	1.49
E	3.36	2.76	0.54	0.00	0.00	0.00	0.00	0.00	6.66	1.31
ESE	1.14	0.30	0.00	0.00	0.00	0.00	0.00	0.00	1.44	0.79
SE	0.60	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.62
SSE	0.96	0.18	0.00	0.00	0.00	0.00	0.00	0.00	1.14	0.56
S	1.44	0.36	0.12	0.00	0.00	0.00	0.00	0.00	1.92	0.90
SSW	1.26	0.30	0.12	0.00	0.00	0.00	0.00	0.00	1.68	0.87
SW	1.86	0.54	0.24	0.00	0.00	0.00	0.00	0.00	2.64	1.08
WSW	2.46	1.14	0.48	0.06	0.00	0.00	0.00	0.00	4.14	1.30
W	5.40	2.16	1.02	0.00	0.00	0.00	0.00	0.00	8.58	1.09
WNW	5.16	0.96	0.06	0.00	0.00	0.00	0.00	0.00	6.18	0.44
NW	8.16	1.08	0.12	0.00	0.00	0.00	0.00	0.00	9.36	0.61
NNW	9.54	0.96	0.06	0.00	0.00	0.00	0.00	0.00	10.56	0.57
TOTAL	68.85	27.55	3.48	0.12	0.00	0.00	0.00	0.00	100.00	0.93

Table C-3-9
U S Borax

Quartz Hill Molybdenum Project Mine Development

Quartz Hill Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS F

800 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	9.25	3.50	0.00	0.00	0.00	0.00	0.00	0.00	12.75	0.79
NNE	3.50	2.50	0.00	0.00	0.00	0.00	0.00	0.00	6.00	1.00
NE	2.63	1.75	0.00	0.00	0.00	0.00	0.00	0.00	4.38	0.97
ENE	2.25	0.88	0.00	0.00	0.00	0.00	0.00	0.00	3.13	0.84
E	1.25	0.50	0.00	0.00	0.00	0.00	0.00	0.00	1.75	0.78
ESE	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.47
SE	0.38	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.68
SSE	0.88	0.25	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.79
S	1.63	0.63	0.00	0.00	0.00	0.00	0.00	0.00	2.25	0.86
SSW	2.25	1.50	0.00	0.00	0.00	0.00	0.00	0.00	3.75	0.87
SW	2.88	1.63	0.00	0.00	0.00	0.00	0.00	0.00	4.50	0.84
WSW	6.13	3.38	0.00	0.00	0.00	0.00	0.00	0.00	9.50	0.91
W	8.38	7.75	0.13	0.00	0.00	0.00	0.00	0.00	16.25	1.03
WNW	7.63	3.38	0.00	0.00	0.00	0.00	0.00	0.00	11.00	0.84
NW	8.25	2.38	0.00	0.00	0.00	0.00	0.00	0.00	10.63	0.78
NNW	9.50	2.38	0.00	0.00	0.00	0.00	0.00	0.00	11.88	0.71
TOTAL	67.25	32.63	0.13	0.00	0.00	0.00	0.00	0.00	100.00	0.86

Table C-3-10
U S Borax

Quartz Hill Molybdenum Project Mine Development

Tunnel Creek Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS A

1268 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	1.50	1.26	0.24	0.00	0.00	0.00	0.00	0.00	3.00	1.30
NNE	0.32	0.79	0.00	0.00	0.00	0.00	0.00	0.00	1.10	1.33
NE	0.24	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.47	1.22
ENE	0.39	0.39	0.16	0.00	0.00	0.00	0.00	0.00	0.95	1.57
E	0.32	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.33
ESE	0.87	0.79	0.00	0.00	0.00	0.00	0.00	0.00	1.66	1.16
SE	0.63	0.39	0.08	0.00	0.00	0.00	0.00	0.00	1.10	1.19
SSE	1.81	1.66	0.00	0.00	0.00	0.00	0.00	0.00	3.47	1.18
S	3.94	2.60	0.00	0.00	0.00	0.00	0.00	0.00	6.55	1.03
SSW	3.39	1.74	0.16	0.00	0.00	0.00	0.00	0.00	5.28	1.04
SW	5.68	2.84	0.08	0.00	0.00	0.00	0.00	0.00	8.60	0.97
WSW	6.94	5.52	0.16	0.00	0.00	0.00	0.00	0.00	12.62	1.09
W	12.30	14.35	0.95	0.00	0.00	0.00	0.00	0.00	27.60	1.35
WNW	5.44	9.62	3.23	0.08	0.00	0.00	0.00	0.00	18.38	1.86
NW	2.37	3.23	0.39	0.00	0.00	0.00	0.00	0.00	5.99	1.41
NNW	1.10	1.34	0.08	0.00	0.00	0.00	0.00	0.00	2.52	1.29
TOTAL	47.24	47.16	5.52	0.08	0.00	0.00	0.00	0.00	100.00	1.33

Table C-3-11
U S Borax

Quartz Hill Molybdenum Project Mine Development

Tunnel Creek Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS B

1012 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	2.57	1.48	0.00	0.00	0.00	0.00	0.00	0.00	4.05	0.90
NNE	0.99	0.69	0.00	0.00	0.00	0.00	0.00	0.00	1.68	1.05
NE	1.09	0.40	0.10	0.00	0.00	0.00	0.00	0.00	1.58	1.09
ENE	1.48	0.89	0.00	0.00	0.00	0.00	0.00	0.00	2.37	0.91
E	2.17	1.98	0.10	0.00	0.00	0.00	0.00	0.00	4.25	1.12
ESE	1.28	1.68	0.40	0.00	0.00	0.00	0.00	0.00	3.36	1.48
SE	1.19	0.89	0.00	0.00	0.00	0.00	0.00	0.00	2.08	0.93
SSE	1.68	0.69	0.00	0.00	0.00	0.00	0.00	0.00	2.37	0.95
S	3.06	1.19	0.00	0.00	0.00	0.00	0.00	0.00	4.25	0.88
SSW	2.47	1.28	0.00	0.00	0.00	0.00	0.00	0.00	3.75	0.83
SW	5.24	1.09	0.00	0.00	0.00	0.00	0.00	0.00	6.32	0.75
WSW	5.53	3.36	0.30	0.00	0.00	0.00	0.00	0.00	9.19	1.07
W	13.83	15.71	0.89	0.00	0.00	0.00	0.00	0.00	30.43	1.27
WNW	6.42	5.93	2.87	0.00	0.00	0.00	0.00	0.00	15.22	1.69
NW	3.66	2.08	0.10	0.00	0.00	0.00	0.00	0.00	5.83	1.07
NNW	2.17	1.09	0.00	0.00	0.00	0.00	0.00	0.00	3.26	0.88
TOTAL	54.84	40.42	4.74	0.00	0.00	0.00	0.00	0.00	100.00	1.18

Table C-3-12
U S Borax

Quartz Hill Molybdenum Project Mine Development

Tunnel Creek Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS C

750 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	3.87	0.80	0.00	0.00	0.00	0.00	0.00	0.00	4.67	0.79
NNE	3.33	0.93	0.13	0.00	0.00	0.00	0.00	0.00	4.40	0.87
NE	1.87	1.47	0.00	0.00	0.00	0.00	0.00	0.00	3.33	1.03
ENE	3.33	2.00	0.00	0.13	0.00	0.00	0.00	0.00	5.47	1.14
E	6.80	9.20	0.00	0.00	0.00	0.00	0.00	0.00	16.00	1.14
ESE	1.60	1.73	0.00	0.00	0.00	0.00	0.00	0.00	3.33	1.10
SE	1.33	0.67	0.00	0.00	0.13	0.00	0.00	0.00	2.13	1.16
SSE	2.00	2.00	0.13	0.00	0.00	0.00	0.00	0.00	4.13	1.04
S	4.27	0.67	0.00	0.00	0.00	0.00	0.00	0.00	4.93	0.63
SSW	3.33	1.07	0.00	0.00	0.00	0.00	0.00	0.00	4.40	0.81
SW	3.60	1.60	0.00	0.00	0.00	0.00	0.00	0.00	5.20	0.83
WSW	4.67	0.93	0.00	0.00	0.00	0.00	0.00	0.00	5.60	0.72
W	12.53	4.53	0.00	0.00	0.00	0.00	0.00	0.00	17.07	0.81
WNW	6.80	1.87	0.13	0.00	0.00	0.00	0.00	0.00	8.80	0.91
NW	4.40	2.00	0.00	0.00	0.00	0.00	0.00	0.00	6.40	0.89
NNW	2.80	1.07	0.27	0.00	0.00	0.00	0.00	0.00	4.13	1.04
TOTAL	66.53	32.53	0.67	0.13	0.13	0.00	0.00	0.00	100.00	0.93

Table C-3-13
U S Borax

Quartz Hill Molybdenum Project Mine Development

Tunnel Creek Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS D

1264 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	4.19	0.71	0.08	0.00	0.00	0.00	0.00	0.00	4.98	0.68
NNE	2.29	1.42	0.16	0.08	0.00	0.08	0.00	0.00	4.03	1.27
NE	1.82	0.55	0.87	0.16	0.08	0.00	0.00	0.00	3.48	1.99
ENE	9.26	3.48	0.24	0.00	0.16	0.00	0.00	0.00	13.13	1.00
E	14.16	30.70	0.55	0.08	0.00	0.00	0.00	0.00	45.49	1.23
ESE	1.27	1.03	0.00	0.00	0.00	0.00	0.00	0.00	2.29	0.99
SE	0.95	0.47	0.08	0.00	0.00	0.00	0.00	0.00	1.50	1.13
SSE	1.11	0.47	0.00	0.00	0.00	0.00	0.00	0.00	1.58	0.86
S	1.58	0.24	0.00	0.00	0.00	0.00	0.00	0.00	1.82	0.68
SSW	1.42	0.63	0.08	0.00	0.00	0.00	0.00	0.00	2.14	0.91
SW	1.50	0.16	0.00	0.00	0.00	0.00	0.00	0.00	1.66	0.62
WSW	1.98	0.24	0.08	0.00	0.00	0.00	0.00	0.00	2.29	0.72
W	3.40	1.03	0.00	0.00	0.00	0.00	0.00	0.00	4.43	0.71
WNW	3.01	1.11	0.08	0.00	0.00	0.00	0.00	0.00	4.19	0.90
NW	3.24	1.11	0.00	0.00	0.00	0.00	0.00	0.00	4.35	0.86
NNW	2.14	0.47	0.00	0.00	0.00	0.00	0.00	0.00	2.61	0.69
TOTAL	53.32	43.83	2.22	0.32	0.24	0.08	0.00	0.00	100.00	1.08

Table C-3-14
U S Borax

Quartz Hill Molybdenum Project Mine Development

Tunnel Creek Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS E

1632 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	5.21	1.59	0.06	0.00	0.00	0.00	0.00	0.00	6.86	0.80
NNE	2.76	1.78	0.06	0.00	0.00	0.00	0.00	0.00	4.60	0.99
NE	1.78	1.16	0.92	0.00	0.00	0.00	0.00	0.00	3.86	1.65
ENE	10.91	5.94	0.25	0.00	0.00	0.00	0.00	0.00	17.10	0.95
E	12.25	27.94	0.06	0.00	0.00	0.00	0.00	0.00	40.26	1.21
ESE	1.29	1.53	0.00	0.00	0.00	0.00	0.00	0.00	2.82	1.08
SE	2.14	0.49	0.00	0.00	0.00	0.00	0.00	0.00	2.63	0.73
SSE	0.92	0.55	0.00	0.00	0.00	0.00	0.00	0.00	1.47	1.01
S	2.08	0.31	0.00	0.00	0.00	0.00	0.00	0.00	2.39	0.61
SSW	1.59	0.55	0.00	0.06	0.00	0.00	0.00	0.00	2.21	0.95
SW	0.80	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.70
WSW	1.65	0.18	0.00	0.00	0.00	0.00	0.00	0.00	1.84	0.56
W	3.43	0.55	0.06	0.00	0.00	0.00	0.00	0.00	4.04	0.64
WNW	2.33	0.43	0.06	0.00	0.00	0.00	0.00	0.00	2.82	0.72
NW	3.06	0.31	0.18	0.00	0.00	0.00	0.00	0.00	3.55	0.74
NNW	1.90	0.61	0.12	0.00	0.00	0.00	0.00	0.00	2.63	0.90
TOTAL	54.11	44.06	1.78	0.06	0.00	0.00	0.00	0.00	100.00	1.03

Table C-3-15
U S Borax

Quartz Hill Molybdenum Project Mine Development

Tunnel Creek Meteorological Data Joint Frequency Distribution

ANNUAL FREQUENCY DISTRIBUTION (IN PERCENT)

STABILITY CLASS F

1873 OBSERVATIONS

WIND SPEED (MPS)

	0 - 1	1 - 3	3 - 5	5 - 7	7 - 9	9 -11	11-13	>13	TOTAL	AVERAGE
N	6.41	1.92	0.00	0.00	0.00	0.00	0.00	0.00	8.33	0.85
NNE	3.42	2.19	0.00	0.00	0.00	0.00	0.00	0.00	5.61	0.93
NE	4.16	2.83	0.00	0.00	0.00	0.00	0.00	0.00	6.99	1.10
ENE	8.17	6.89	0.00	0.00	0.00	0.00	0.00	0.00	15.06	1.04
E	5.66	7.10	0.00	0.00	0.00	0.00	0.00	0.00	12.76	1.03
ESE	1.92	0.91	0.00	0.00	0.00	0.00	0.00	0.00	2.83	0.83
SE	1.55	1.28	0.00	0.00	0.00	0.00	0.00	0.00	2.83	0.95
SSE	1.39	0.75	0.00	0.00	0.00	0.00	0.00	0.00	2.14	0.98
S	3.68	1.12	0.00	0.00	0.00	0.00	0.00	0.00	4.81	0.77
SSW	2.62	0.96	0.00	0.00	0.00	0.00	0.00	0.00	3.58	0.73
SW	1.87	0.64	0.00	0.00	0.00	0.00	0.00	0.00	2.51	0.81
WSW	4.16	0.91	0.00	0.00	0.00	0.00	0.00	0.00	5.07	0.68
W	5.39	1.92	0.00	0.00	0.00	0.00	0.00	0.00	7.31	0.82
WNW	5.77	1.17	0.00	0.00	0.00	0.00	0.00	0.00	6.94	0.73
NW	6.73	1.55	0.00	0.00	0.00	0.00	0.00	0.00	8.28	0.80
NNW	4.22	0.75	0.00	0.00	0.00	0.00	0.00	0.00	4.97	0.73
TOTAL	67.11	32.89	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.89

TABLE C-3-16

MONTHLY QUARTZ HILL
TEMPERATURE AND WIND SPEED DISTRIBUTIONS

Month	Monthly Maximum	Monthly Minimum	Monthly Average	Number of Hours of Sub-Freezing Temperatures
Temperatures (C):				
January	7	-18	-6.7	624
February	6	-10	-3.1	455
March	7	-6	-0.3	329
April	9	-4	0.3	209
May	18	-4	4.0	36
June	24	2	11.5	0
July	32	5	11.9	0
August	25	4	10.0	0
September	20	1	8.1	0
October	8	-1	2.8	14
November	8	-6	1.1	158
December	6	-17	-2.7	487
Annual	32	-18	3.1	2,312
Wind Speed (mph):				
January	19.4	0.0	5.4	
February	20.2	0.2	5.3	
March	20.6	0.0	3.5	
April	18.4	0.0	4.7	
May	16.0	0.2	3.3	
June	9.0	0.0	2.6	
July	9.8	0.0	2.6	
August	9.4	0.0	2.4	
September	8.4	0.0	0.3	
October	15.6	0.0	2.1	
November	13.0	0.0	4.4	
December	17.0	0.0	4.1	
Annual	20.6	0.0	3.4	

TABLE C-3-17

MONTHLY TUNNEL CREEK
TEMPERATURE AND WIND SPEED DISTRIBUTIONS

Month	Monthly Maximum	Monthly Minimum	Monthly Average	Number of Hours of Sub-Freezing Temperatures
Temperatures (C):				
January	7	-5	0.9	179
February	6	-3	1.2	70
March	11	-3	4.1	9
April	15	-4	3.8	107
May	31	-1	8.4	19
June	28	4	12.2	0
July	29	2	14.1	0
August	25	8	13.0	0
September	17	1	9.1	0
October	11	-1	5.7	7
November	8	-4	2.5	96
December	12	-12	-1.9	408
Annual	31	-12	6.1	895
Wind Speed (mph):				
January	7.2	0.6	2.0	
February	7.0	0.5	1.8	
March	9.0	0.0	2.1	
April	7.8	0.2	2.6	
May	9.8	0.1	2.5	
June	8.4	0.2	2.6	
July	12.2	0.6	3.3	
August	9.0	0.6	2.3	
September	7.0	0.6	2.0	
October	9.2	0.6	1.8	
November	21.4	0.6	2.9	
December	13.4	0.0	2.7	
Annual	21.4	0.0	2.4	

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Utilizing the above definition, the frequency of calm occurrences for the Quartz Hill and Tunnel Creek meteorology is 5.0 and 5.2 percent, respectively. The distribution of the number of days by the number of calms per day, for both the Quartz Hill and Tunnel Creek data, are as follows:

	Number of Days with Calms	
Hours per Day	Quartz Hill	Tunnel Creek
1	91	118
2	43	65
3	31	30
4	12	14
5	5	5
6	4	4
7	3	1
8	2	0
9	0	0
10	1	1
11	2	0

3.3 ATMOSPHERIC STABILITY FACTOR DETERMINATION

The atmospheric stability factors were determined from the on-site wind data by using two methods. At the mine site, the stability class data were determined from wind sigma theta measurements recorded at the 150-ft Quartz Hill tower. At Tunnel Creek, the stability factors were estimated by analysis of the wind direction range recorded on strip charts from the two weather stations. For both the mine site and Tunnel Creek, the stability class data were further modified to account for nighttime stability conditions. The procedure used to determine stability class and adjust stability class for nighttime conditions is presented in Table C-3-18. For the purposes of this operation, "nighttime" was defined as one hour prior to the time of sunset to one hour after the time of sunrise (EPA 1984b, p. 9-20).

TABLE C-3-18

STABILITY CATEGORY DETERMINATIONS[1/]
STABILITY CLASS FROM SIGMA THETA

Stability Category	Range of Wind Direction Standard Deviation, Degrees
A	$\sigma_\theta \geq 22.5$
B	$22.5 \geq \sigma_\theta \geq 17.5$
C	$17.5 \geq \sigma_\theta \geq 12.5$
D	$12.5 \geq \sigma_\theta \geq 7.5$
E	$7.5 \geq \sigma_\theta \geq 3.8$
F	$3.8 \geq \sigma_\theta$

NIGHTTIME METHOD [1/]
FOR ADJUSTING STABILITY CLASS

If the stability class is	and if the wind speed (u) is (mps)	Then the nighttime stability class is
	$u \leq 2.9$	F
A	$2.9 < u \leq 3.6$	E
	$3.6 \leq u$	D
	$u \leq 2.4$	F
B	$2.4 < u \leq 3.0$	E
	$3.0 \leq u$	D
C	$u \leq 2.4$	E
	$2.4 \leq u$	D
D	no restriction	D
E	$u \leq 5.0$	E
	$5.0 \leq u$	D
F	$u \leq 3.0$	
	$3.0 \leq u \leq 5.0$	F
		E
	$5.0 \leq u$	D

1/ Source: EPA (1984b)

4.0 MODELING APPROACH

In this section, the modeling assumptions used to predict the ambient concentrations of pollutants near the mine site and the Tunnel Creek site are described. The assumed fugitive dust characteristics are listed, the stack emission parameters for the Tunnel Creek power plant are described, and the specific computer models used are described.

4.1 COMPILATION OF PARTICULATE EMISSIONS FOR COMPUTER MODELING

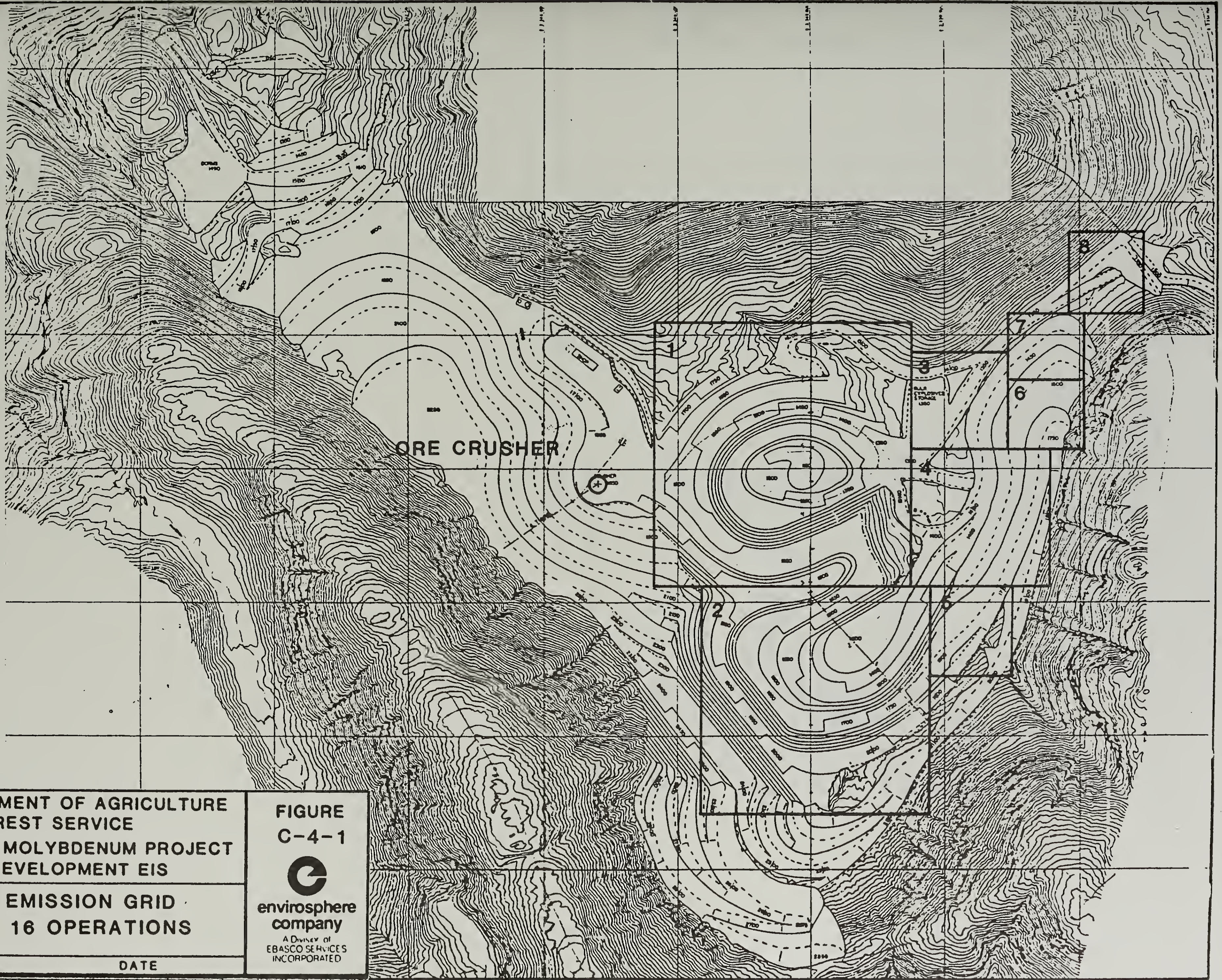
The impacts of the particulate emissions from the mine site were modeled using the Industrial Source Complex (ISC) computer models. The combined fugitive dust and tailpipe emissions were assumed to be emitted from eight ground level area sources and one point source, as shown in Figure C-4-1. The worst case 24-hour particulate emission rates from each of the emission cells are listed in Table C-4-1.

4.2 FUGITIVE DUST MODELING

Fugitive dust from the mining operations and from the Tunnel Creek ore loading operations was modeled using the ISC computer models. The ISC models utilize sequential hourly meteorology (ISCST), joint frequency distributions of wind speed, wind direction, and stability class (ISCLT), and account for particle fallout. Sources of mine site fugitive dust include emissions from drilling and blasting, waste rock handling, coarse ore conveying, the haul roads, tailpipe emissions, and wind erosion of exposed surfaces. The largest source of emissions will be the mine. Because mine source emissions are below the level of surrounding terrain, fugitive emissions were modeled as a series of large ground level area sources. It is assumed that the plume is released at ground level and stays on the ground at all times (vertical motion only by diffusion). Modeling of haul road emissions in combination with other mine emissions introduces a degree of conservatism into the results and eliminates the need for a complicated source configuration.

The particle settling velocities shown in Table C-4-2 were calculated using the equation specified in the ISC Users Manual (EPA 1984) and an assumed particle density of 2.5 g/cm^3. The particle reflection coefficients were determined from the ISC Users Manual.

The worst case 24-hour TSP impacts at the mine site were modeled using the ISCST computer model. The maximum 24-hour average emission rates shown in Section 2.0 were used. All fugitive dust emissions were assumed to be emitted at ground level from the eight area sources shown in Figure C-4-1. A two step process was used to model the highest 24-hour average impacts for the period 1981-82, for which meteorological data were available. First, a screening run using



SCALE

1000 ft

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MINE SITE EMISSION GRID
FOR YEAR 16 OPERATIONS

SOURCE | DATE

FIGURE C-4-1

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TABLE C-4-1
MINE SITE TSP EMISSION GRID EMISSION RATES (LBS/HR)

Operation	Mining Sources (Squares 1,2)	Waste Rock Sources (Squares 3-8)	Ore Crusher
Drilling	0.5	0	0
Blasting	8.5	0	0
Waste Rock Loading	0.1	0	0
Waste Rock Haul Road	45.2	90.4	0
Waste Rock Hauling Tailpipe	8.8	17.6	0
Ore Loading	0.1	0	0
Ore Haul Road	110.6	0	0
Ore Haul Road Tailpipe	26.4	0	0
Waste Rock Dumping	0	0.1	0
Waste Rock Wind Erosion	0	0.9	0
Primary Ore Crusher	0	0	0.7
Total Emissions (lbs/hr)	200.2	109.0	0.7

1/ See Figure C-4-1 for Source Locations

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TABLE C-4-2

ASSUMED PARTICLE SIZE DISTRIBUTION

Particle size (microns)	Settling Velocity (cm/sec)	Reflection Coeff. (dimensionless)	Mass Fraction (percent)
30	6.7	0.60	10.5
24	4.3	0.65	13.0
19	2.7	0.70	14.0
15	1.7	0.75	10.0
12	1.1	0.80	15.1
8	0.50	0.85	3.7
7	0.36	0.90	8.8
5	0.18	0.90	5.0
4	0.12	0.95	2.5
3.5	0.09	0.95	2.5
3	0.06	1.0	6.2
2	0.03	1.0	0.6
1.8	0.02	1.0	1.9
1.5	0.016	1.0	2.5
1.0	0.007	1.0	3.6

hourly meteorological data for the period 1981-82 was run, to identify the data day that resulted in the maximum 24-hour TSP impact along the project boundary. The results of the mine site screening analysis are shown in Table C-4-3. The screening run indicated that the highest 24-hour TSP impact would be 133 ug/m^3, and would occur using the hourly wind data for Data Day 263. The second-highest impact would be only 125 ug/m^3, and would occur using the wind data for Day 246. The measured wind data for Data Day 263 are listed in Table C-4-4. The ISCST computer model was then used to predict the 24-hour TSP impacts, accounting for particle settling.

For the screening analysis at the mine site, the assumed worst case fugitive dust values during the period October through May were reduced by a scalar factor of 0.198, to account for continuous snow cover during that period. It was assumed that snow cover would eliminate fugitive dust from the haul roads. The 0.198 factor was determined as follows:

$$\frac{\text{Emissions Excluding Haul Road Dust}}{\text{Worst Case 24-hour Emissions}} = \frac{60.7 \text{ lbs/hr}}{308 \text{ lbs/hr}} = 0.198$$

The annual average TSP impacts at the mine were calculated using the ISCLT computer model. Meteorological data for the period 1981-82 were used. The annual average particulate emissions shown in Section 2.0 were used, accounting for particle settling.

For both the ISCST and ISCLT models, calms were defined as follows: wind speed less than 1.0 mps and wind direction variation less than 10 degrees from the previous hour. In accordance with the EPA guidelines, all calm periods were eliminated from the wind data used in the computer calculations (EPA 1984b).

4.3 TUNNEL CREEK POWER PLANT MODELING

The annual average and short-term impacts of stack emissions from the Tunnel Creek power plant were modeled using the COMPLEX I computer model. The stack emission parameters described in Section 2.3.1 of this appendix were used. The Tunnel Creek wind data described in Chapter 3.0 were used. Where calm periods were measured, those periods were excluded from the calculations in accordance with EPA guidelines (EPA 1984b). Because it is presumed that the maximum impacts will occur on elevated terrain near the plant, the effects of reduced mixing height should not be significant at Tunnel Creek. An unlimited mixing height was therefore used. The measured sequential hourly wind data for the Tunnel Creek site were used.

The fugitive dust impacts at Tunnel Creek were calculated using the ISCST and ISCLT computer models. The power plant stack emissions were not included in the fugitive dust modeling because the stack emissions are expected to travel far beyond the area affected by fugitive dust before the plume touches the ground. The measured sequential hourly wind data for the year 1984 were used. To calculate the worst case 24-hr impacts, a two step process was used. First, a screening run indicated that the wind data for Day 358 resulted in the highest

TABLE C-4-3
RESULTS OF MINE SITE TSP SCREENING RUN

Direction from Ore Crusher 1/ (Degrees)	Distance to Boundary (km)	Maximum Impact (ug/m^3)	Data Day
0° (North)	1.8	44	227
10	1.8	47	227
20	1.8	46	264
30	2.1	32	264
40	4.6	26	274
50	6.0	46	254
60	5.2	25	282
70	5.7	31	244
80	5.8	27	266
90 (East)	5.8	39	266
100	5.4	41	263
110	5.1	100	263
120	3.2	133	263
130	2.8	125	246
140	2.7	107	246
150	2.7	88	272
160	2.7	85	272
170	2.5	57	301
180 (South)	2.5	51	301
190	2.8	100	299
200	2.1	101	125
210	1.5	91	125
220	1.4	97	299
230	1.2	79	299
240	1.2	56	125
250	1.3	51	203
260	1.3	47	203
270 (West)	1.4	36	203
280	1.6	27	203
290	2.2	20	203
300	2.1	18	133
310	2.1	20	133
320	2.1	19	133
330	2.2	14	275
340	2.4	24	275
350	2.2	28	275

1/ Ore crusher was used as datum for mine site emission grid and receptor grid. See Figures C-1-2 and C-4-1 for ore crusher location.

Table C-4-4

* METEOROLOGICAL DATA FOR DAY 263 *

HOUR	FLOW VECTOR (DEGREES)	RANDOM FLOW VECTOR (DEGREES)	WIND SPEED (MPS)	MIXING HEIGHT (METERS)	TEMP. (DEG. K)	INPUT STABILITY CATEGORY	ADJUSTED STABILITY CATEGORY
1	0.0	117.0	1.00	9999.0	278.0	5	5
2	0.0	132.0	1.00	9999.0	278.0	5	5
3	0.0	166.0	1.00	9999.0	278.0	5	5
4	0.0	148.0	1.00	9999.0	277.0	4	4
5	0.0	134.0	1.00	9999.0	277.0	4	4
6	0.0	114.0	1.00	9999.0	277.0	4	4
7	0.0	131.0	1.00	9999.0	278.0	4	4
8	0.0	143.0	1.00	9999.0	278.0	4	4
9	1.0	146.0	1.00	9999.0	278.0	3	3
10	0.0	274.0	1.00	9999.0	280.0	2	2
11	0.0	256.0	1.00	9999.0	282.0	3	3
12	0.0	302.0	1.00	9999.0	282.0	2	2
13	0.0	10.0	1.00	9999.0	283.0	1	1
14	0.0	282.0	1.00	9999.0	283.0	1	1
15	0.0	252.0	1.00	9999.0	283.0	2	2
16	1.0	246.0	1.00	9999.0	283.0	2	2
17	0.0	311.0	1.00	9999.0	283.0	2	2
18	0.0	155.0	1.00	9999.0	282.0	3	3
19	0.0	122.0	1.00	9999.0	282.0	4	4
20	1.0	130.0	1.00	9999.0	282.0	5	5
21	0.0	105.0	1.00	9999.0	282.0	6	6
22	0.0	165.0	1.00	9999.0	282.0	6	6
23	0.0	100.0	1.00	9999.0	282.0	6	6
24	0.0	113.0	1.00	9999.0	282.0	6	6

impacts at the project boundary. Second, a fine receptor grid was used with the wind data for that day to calculate the maximum 24-hr average isopleths.

4.4 MINE SITE TAILPIPE EMISSIONS

The tailpipe emissions of NO_x were assumed to be evenly distributed among the entire emission grid shown in Figure C-4-1. The annual average NO_x impacts were calculated using the ISCLT computer model. All tailpipe emissions are assumed to be emitted at ground level.

4.5 TAILINGS DISPOSAL DAM IMPACTS

The 24-hour impacts of the tailings dam construction at Tunnel Creek were calculated using the ISCST computer model. The wind was assumed to blow downvalley at 2.5 mps under F stability conditions with unlimited mixing height. The dam was modeled as an area source, with a base elevation of 300 ft and a top elevation of 600 ft. Particle settling was included in the calculations, with an assumed particle size distribution identical to that used for the mining operation emissions.

4.6 ALTERNATIVE POWER PLANT SITE IMPACTS

The impacts of stack emissions from the alternative Beaver Creek power plant were estimated using the EPA approved worst case screening analyses (EPA 1977). The stack parameters and plume rise were assumed to be identical to those for the Tunnel Creek power plant. Winds were assumed to blow downvalley at 2.5 mps during F-class stability for six hours per day.

The impacts of stack emissions at the North Meadow power plant were estimated by using the same approach that was used to predict the Beaver Creek plant impacts. The winds were assumed to blow downvalley at 2.5 mps under F-class stability.

4.7 ACCESS ROAD FUGITIVE DUST IMPACTS

The fugitive dust impacts near the access road were estimated using a worst case analysis, using the ISCST computer model. It was assumed that the fugitive dust emissions per unit length of road were constant along the entire road. The worst case emissions for a dry day were used. The wind was assumed to blow at 2.5 m/second, perpendicular to the road, for 6 hrs/day in each direction. Dust settling was included in the computer calculations.

5.0 MODELING RESULTS

5.1 TUNNEL CREEK IMPACTS

The calculated impacts of the Tunnel Creek emissions are summarized in Table C-5-1. In no cases do the calculated impacts exceed the applicable regulatory limits.

The predicted worst case impacts from the power plant plume occur when the wind blows across the valley. The power plant plume rises above the ridges near the plant, and impacts the higher terrain to the south. The predicted worst case SO_2 impacts are much less than the PSD Class II increments. The impacts of the other pollutants are much less than the ASAAQS limits.

The predicted worst case fugitive dust impacts at Tunnel Creek occur when the wind blows downvalley. As shown in Table C-5-1, the predicted worst case impacts are much less than the applicable regulatory limits.

5.2 MINE SITE IMPACTS

The calculated air quality impacts at the mine site are summarized in Table C-5-1. In no cases do the predicted impacts exceed the ASAAQS limits (note that the mine site operations are not subject to PSD review).

The predicted worst case 24-hour fugitive dust isopleths are shown in Figure C-5-1. The predicted worst case impacts occur when the winds blow eastward. As shown in the figure, the calculated impacts at the project boundary do not exceed the allowable 150 ug/m^3 concentration.

5.3 TUNNEL CREEK ACCESS ROAD IMPACTS

The fugitive dust impacts of the Tunnel Creek access road and the mine access road are shown in Figure C-5-2. The ISCST model, with dust settling, was used. That model does not compute concentrations at receptors closer than 100 m from the sources, so the concentrations shown in Figure C-5-2 apply only to downwind distances greater than 100 m.

As shown in the figure, the calculated 24-hour TSP impacts on a dry day with low wind speed would be insignificant near either access road. At distances greater than 100 m, the TSP impacts would be less than existing background value. At distances closer to the road shoulder, it is unlikely that the worst cast TSP impact would approach the allowable 150 ug/m^3 ASAAQS limit.

The predicted fugitive dust concentrations near the Tunnel Creek access road are shown in Figure C-5-2. The fugitive dust impacts are predicted to be much less than the allowable ASAAQS limit (note that the access road is not subject to PSD review).

TABLE C-5-1
CALCULATED WORST CASE AIR QUALITY IMPACTS

Pollutant and Averaging Time	Maximum Impact (ug/m^3)	PSD Class II Increment (ug/m^3)	Alaska Ambient Standard (ug/m^3)
TUNNEL CREEK			
Power Plant Particulates (TSP)			
o Annual	5.2 1/	N/A 2/	60
o 24-hr	7.5 1/	N/A	150
Power Plant SO_2			
o Annual	1.81	20	80
o 24-hr	21.5	91	365
o 3-hr	39.7	512	1,300
Power Plant NO_x			
o Annual	5.1	None Established	100
Fugitive Dust (TSP)			
o Annual	5.1 1/	N/A	60
o 24-hr	10.0 1/	N/A	150
PM-10 Particulates			
o Annual	Less tnan 5	None	50
o 24-hr	Less than 10	None	150
MINE SITE			
Fugitive Dust and Tailpipe TSP			
o Annual	6 1/	N/A 2/	60
o 24-hr	146 1/	N/A	150
Nitrogen Oxides			
o Annual	47	None Established	100
PM-10 Particulates			
o Annual	Less than 6	None	50
o 24-hr	Less than 146	None	150

1/ Includes 5 ug/m^3 background value for TSP.
2/ PSD increments do not apply at mine site. PSD increments do not apply for TSP at either Tunnel Creek or mine site.

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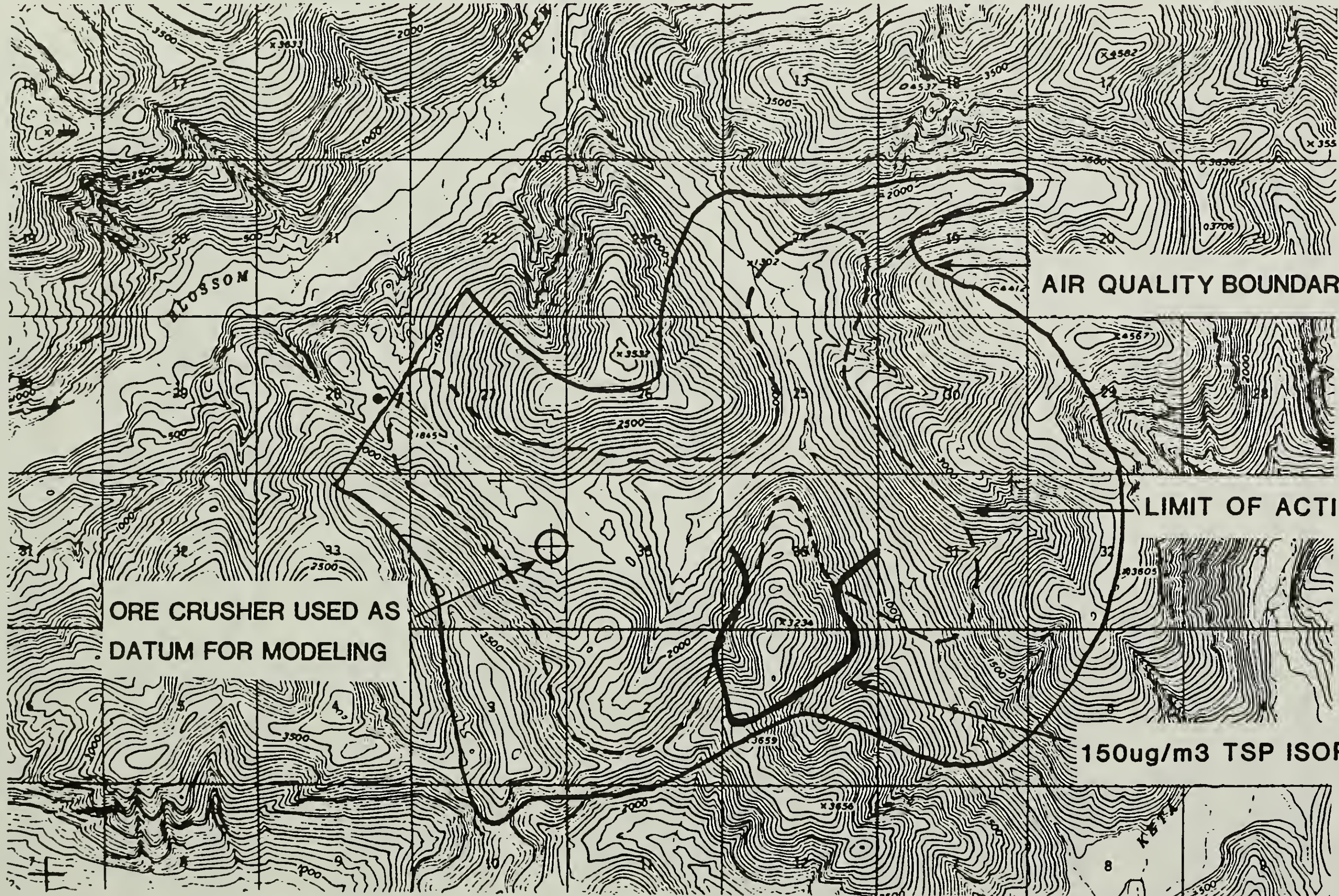

NOTE: INCLUDES ASSUMED
5ug/m3 BACKGROUND
TSP CONCENTRATION

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CALCULATED WORST CASE
24 HOUR TSP IMPACTS AT MINE
SITE FOR DATA PERIOD 1981-82

SOURCE DATE

FIGURE
C-5-1

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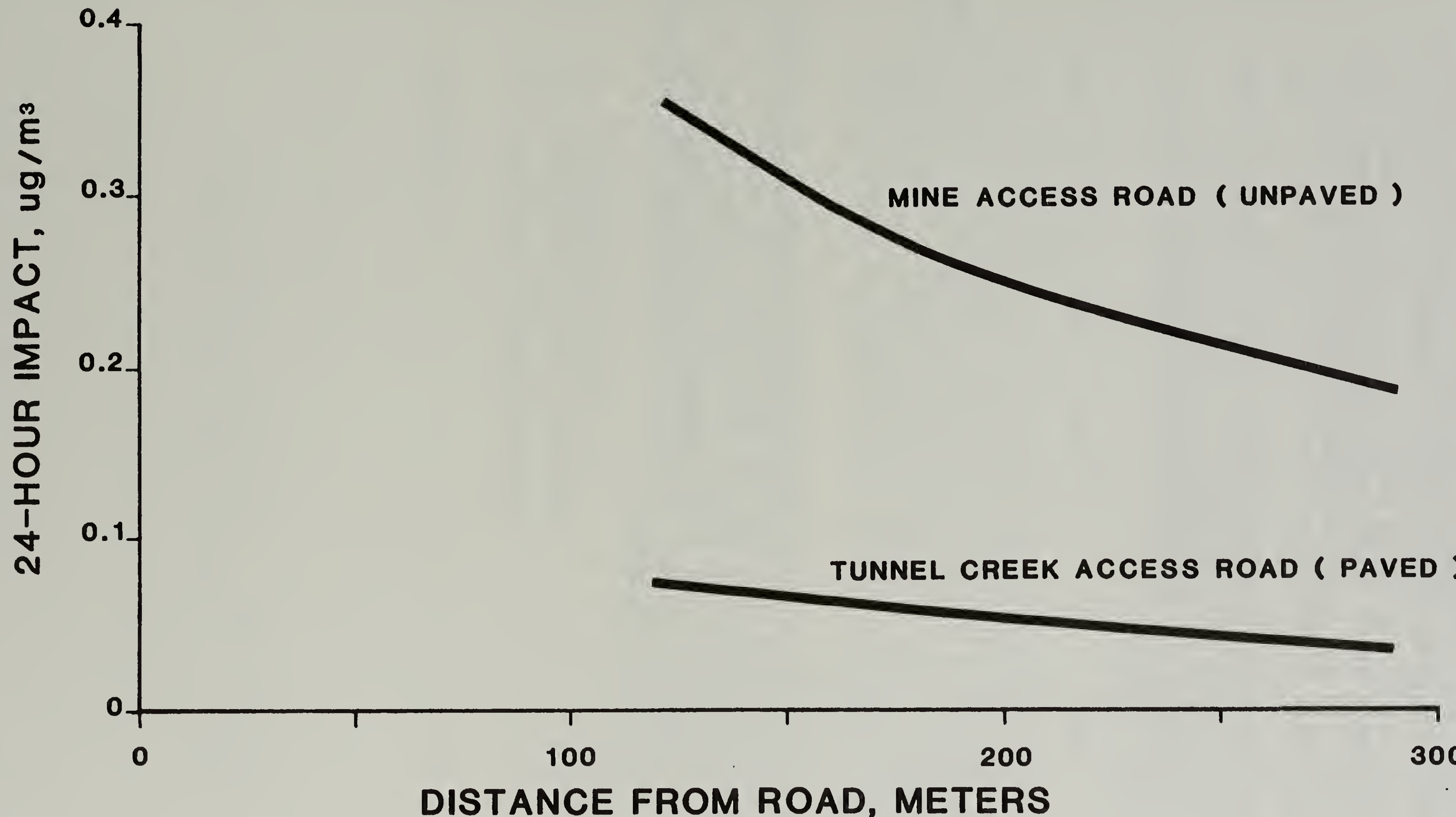

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FOREST SERVICE

QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

PREDICTED 24-HOUR FUGITIVE DUST IMPACTS CAUSED BY ACCESS ROADS.

SOURCE DATE

FIGURE C-5-2

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5.4 BEAVER CREEK AND NORTH MEADOW POWER PLANT IMPACTS

The worst case 24-hr SO_2 impact near the Beaver Creek power plants was estimated using the EPA approved Valley/F/2.5 screening procedure (EPA 1977). The calculated worst case 24-hr SO_2 impact at Beaver Creek was only 7.3 ug/m^3, which is much less than the allowable 24-hr PSD Class II increment of 91 ug/m^3. It is therefore concluded that the impacts of SO_2 and the other pollutants emitted from the Beaver Creek power plant will be much less than the allowable limits.

The calculated worst case 24-hr SO_2 impact at North Meadow was only 4.4 ug/m^3, which is much less than the 91 ug/m^3 PSD Class II increment. It is therefore concluded that the impacts of all pollutants emitted from the North Meadow power plant will be much less than the regulatory limits.

5.5 VISIBILITY IMPACTS

Based on worst-case screening level calculations, neither the Tunnel Creek nor mine site operation would cause any significant visibility impacts in the Wilderness Area. The screening analyses were done using the methods in the EPA Visibility Workbook (EPA 1980). The worst-case pollutant emissions listed in Table C-2-4 were used. The wind was assumed to blow in a straight line from the emission source to the Wilderness Area boundary.

The results of the screening analyses are listed in Table C-5-2. Three visibility factors (C_1, C_2, and C_3) are calculated. As shown in the table, all three visibility factors for each facility are less than the 0.10 limit for possible visibility degradation. This indicates that neither the Tunnel Creek nor the mine site operations are expected to cause any visibility degradation.

TABLE C-5-2

SUMMARY OF PLUME VISIBILITY CALCULATIONS

Item	Tunnel Creek	Mine Site
Distance to Wilderness Boundary (km)	12.8	6.4
Emission Rates (metric tons/day)		
TSP	0.039	1.09
SO_2	0.338	0.0
NO_2	2.37	5.68
Background Visibility Range (km)	40	40
Calculated Visibility Factors 1/		
C_1 = Sky/Plume Contrast	-0.053	-0.080
C_2 = Sky/Black Terrain Contrast	0.017	0.096
C_3 = Sky/White Terrain Contrast	7.5×10^{-5}	1.7×10^{-4}
Conclusion	No Impact	No Impact

1/ If the absolute value of any of the visibility factors exceeds 0.10, then visual degradation may be a problem.

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APPENDIX D
SURFACE WATER HYDROLOGY

APPENDIX D

SURFACE WATER HYDROLOGY

TABLE OF CONTENTS

LIST OF TABLES

METHOD FOR CALCULATING STREAMFLOWS FOR NATURAL AND DISTURBED CONDITIONS

I. NATURAL FLOWS

A. Average Monthly and Annual Flows

The Keta River and White Creek have been continuously gaged since 1977. Average annual flows for water years 1978-1982 were measured to be 768 and 27.5 cfs for the Keta River and White Creek, respectively. Long-term records from the closest gage with a long-term and current record, Fish Creek, show that the long-term average annual flow was 10 percent higher than the average flow for 1978-82 as shown in the table below. Therefore, long-term average annual flows of the Keta River and White Creek were estimated to be 10 percent higher than the gaged flows, or 845 and 30.3 cfs, respectively.

FISH CREEK AVERAGE FLOWS
COMPARISON OF THE LONG-TERM AVERAGE ANNUAL
FLOW TO THE 5-YR AVERAGE ANNUAL FLOW (WATER YEARS 1978-82)

Water Year	Average Annual Flow (cfs)1/
1978	302
1979	404
1980	399
1981	507
1982	310
5-yr average	384
60-yr average	423

Percent difference = $\frac{(423-384)}{384}$ (100) = +10 percent

1/ Source: U.S. Geological Survey (1979, 1980, 1981, 1982, 1983).

Average monthly flows for the Keta River and White Creek were based on the ratio of monthly flow to annual flow as measured during the period 1978 to 1982, and the adjusted annual flows of 845 and 30.3 cfs, respectively, as shown in Table D-1. Monthly flows for the remaining project streams were based on the ratio of flow per unit area of the Keta River (for the Wilson and Blossom rivers) and White Creek (for all other streams) as tabulated in Table D-1. Monthly and annual flows of each project stream are presented in Table D-2.

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TABLE D-1

AVERAGE MONTHLY FLOW OF WHITE CREEK AND KETA RIVER
NATURAL CONDITIONS

	White Creek (Drainage Area = 2.70 mi^2)			Keta River (Drainage Area = 74.2 mi^2)		
Month	Q_R 1/	Q_M (cfs) 2/	Q/A (cfs/mi^2) 3/	Q_R	Q_M (cfs)	Q/A (cfs/mi^2)
October	1.96	59.4	21.9	2.05	1,732	23.3
November	1.09	30.0	12.2	1.09	921	12.4
December	0.74	22.4	8.3	0.74	625	8.4
January	0.52	15.8	5.8	0.48	406	5.5
February	0.41	12.4	4.6	0.32	270	3.6
March	0.49	14.8	5.5	0.37	313	4.2
April	0.80	24.2	8.9	0.57	482	6.5
May	1.49	45.1	16.7	1.38	1,166	15.7
June	1.65	50.0	18.5	1.60	1,352	18.2
July	0.82	24.8	9.2	1.10	930	12.5
August	0.67	20.3	7.5	0.82	693	9.3
September	1.28	38.8	14.3	1.44	1,217	16.4
Annual	1.00	30.3	11.2	1.00	845	11.4

1/ Q_R = (Average monthly flow)/(Average annual flow) as measured by a continuous gage for water years 1978 to 1982.

2/ Q_M = synthetic average monthly flow at the gage location. For White Creek, $Q_M = Q_R$ x (30.3 cfs) and for the Keta River, $Q_M = Q_R$ x (845 cfs). Resulting values are ten percent higher than gaged average monthly flows.

3/ Q/A = Flow per drainage basin area above the gage. For White Creek, Q/A = $Q_M/2.70\ mi^2$ and for the Keta River, Q/A = $Q_M/74.2\ mi^2$.

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TABLE D-2

ESTIMATED AVERAGE MONTHLY FLOW OF PROJECT STREAMS (cfs)
NATURAL CONDITIONS

Basin	Drainage Area (mi^2)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
USING WHITE CREEK FLOW/AREA 1/														
Aronitz (mouth)	9.84	215	120	82	57	45	54	88	164	182	91	74	141	110
Beaver (sed pond)	2.11	46	26	18	12	10	12	19	35	39	19	16	30	24
Beaver (mouth)	2.58	57	31	21	15	12	14	23	43	48	24	19	37	29
Hill (reservoir)	3.06	67	37	25	18	14	17	27	51	57	28	23	44	34
Hill (sed pond)	12.21	267	149	101	71	56	67	109	204	226	112	92	175	137
Hill (mouth)	14.42	316	176	120	84	66	79	128	241	267	133	108	206	162
North Cr (mouth)	1.79	39	22	15	10	8	10	16	30	33	16	13	26	20
Raspberry (reservoir)	1.26	28	15	10	7	6	7	11	21	23	12	9	18	14
Raspberry (mouth)	3.15	69	38	26	18	14	17	28	53	58	29	24	45	35
Smith (mouth)	3.47	76	42	29	20	16	19	31	58	64	32	26	50	39
Tunnel (reservoir)	5.39	118	66	45	31	25	30	48	90	100	50	40	77	60
Tunnel (tailings dam)	9.96	218	122	83	58	46	55	89	166	184	92	75	142	112
Tunnel (mouth)	11.07	242	135	92	64	51	61	99	185	205	102	83	158	124
White (mouth)	2.98	65	36	25	17	14	16	27	50	55	27	22	43	33
USING KETA RIVER FLOW/AREA 2/														
Blossom (mouth)	72.87	1698	904	612	401	262	306	474	1144	1326	911	678	1195	831
Keta (mouth)	78.20	1822	970	657	430	282	328	508	1228	1423	977	727	1282	891
Wilson (well field)	116.00	2703	1438	974	638	418	487	754	1821	2111	1450	1079	1902	1322
Wilson (mouth)	189.90	4425	2355	1595	1044	684	798	1234	2981	3456	2374	1766	3114	2165
1/ White Creek flow/area (cfs/mi^2)		21.9	12.2	8.3	5.8	4.6	5.5	8.9	16.7	18.5	9.2	7.5	14.3	11.2
2/ Keta River flow/area (cfs/mi^2)		23.3	12.4	8.4	5.5	3.6	4.2	6.5	15.7	18.2	12.5	9.3	16.4	11.4

B. Low and Peak Flows

Natural low and peak flows were calculated according to the methodology presented by the Forest Service (1980), which utilizes regression equations developed specifically for the Tongass National Forest. The equations used and the resulting flows are listed in Table D-3.

The average precipitation value used in these equations was determined by evaluating precipitation and streamflow records from the project area. Complete precipitation and streamflow data exist for only one basin for two years (White Creek, 1980 and 1981). During this period, measured streamflow at the White Creek gage (El. 1250) divided by the overall basin area exceeded the measured precipitation at the Quartz Hill camp (El. 1400) by 31 in. and 52 in. for 1980 and 1981, respectively. Since average precipitation should exceed runoff, the precipitation levels measured at the Quartz Hill camp were evidently not representative of the average precipitation occurring over the basin, most likely because of the orographic effect of increased precipitation with higher elevations. Based on data and analyses by Patric and Black (1968), evapotranspiration is estimated to be 20 in./yr in the coastline areas. Based on engineering judgment and professional experience, Lyons (1984) has estimated evapotranspiration to be about 5 in./yr in high headwater basins where temperatures are lower and vegetation is less. Average annual streamflow was estimated to be 11.2 cfs/mi^2 or 152 in. in the White Creek basin (Table D-1). Other losses and gains, such as groundwater discharge or recharge, are assumed to be minimal in this basin. Thus, average annual precipitation in White Creek, a high headwater basin, was estimated to be 157 in. White Creek was assumed to have the same precipitation as several other similar headwater basins including Beaver Creek at the sedimentation pond, Hill Creek at the reservoir site, Hill Creek at the sedimentation pond, and Raspberry Creek at the reservoir site.

Several tributary watersheds are at lower elevations than White Creek. Based on professional judgment, the average annual precipitation in these basins was estimated to be 150 in./yr. This estimate was based largely on orographic effects which result in higher precipitation in the higher elevation watersheds. Lower elevation tributary watersheds include Aronitz Creek at its mouth, Beaver Creek at its mouth, Hill Creek at its mouth, North Creek at its mouth, Raspberry Creek at its mouth, Smith Creek at its mouth, Tunnel Creek at the reservoir site, Tunnel Creek at the dam site, and Tunnel Creek at its mouth.

Precipitation levels over the Blossom, Keta, and Wilson watersheds were estimated from precipitation maps from the Forest Service (1980). Although these maps are at a large scale and are not appropriate for the small tributary stream basins in the project area, the maps are suitable for the large watersheds of the Blossom, Keta, and Wilson rivers. The average precipitation for these rivers was estimated to be 150 in. per year, based on these maps. The average precipitation in

TABLE D-3

ESTIMATED LOW AND PEAK FLOWS[a/]

NATURAL CONDITIONS

Drainage Basin	Area (mi^2)	PPT (in)	Percent Lakes	C (mi)	EMAX (ft)	EMIN (ft)	EAVG (ft)	Q10 (cfs)	Q100 (cfs)	7Q10 (cfs)
Aronitz (mouth)	9.84	150	1.1	47	4750	0	1539	2224	3079	3.7
Beaver (sed pond)	2.11	157	1.0	56	3800	1200	2042	541	749	0.5
Beaver (mouth)	2.58	150	1.0	56	3800	100	1299	742	1012	0.6
Blossom (mouth)	72.87	150	1.0	46	5420	0	1756	13145	18540	48.0
Hill (reservoir)	3.06	157	1.0	50	4582	1500	2499	694	972	0.8
Hill (sed pond)	12.21	157	1.0	50	4582	700	1958	2662	3717	4.8
Hill (mouth)	14.42	150	1.0	50	4582	100	1552	3231	4487	5.8
Keta (mouth)	78.20	150	1.0	46	5000	0	1620	14484	20362	52.6
North (mouth)	1.79	150	1.0	40	4350	100	1477	507	693	0.4
Raspberry (reservoir)	1.26	157	1.0	40	3800	2300	2786	299	419	0.3
Raspberry (mouth)	3.15	150	1.0	55	3800	100	1299	888	1212	0.8
Smith (mouth)	3.47	150	1.0	40	3659	100	1253	983	1340	1.0
Tunnel (reservoir)	5.39	150	1.0	40	4110	500	1670	1295	1794	1.8
Tunnel (dam)	9.96	150	1.0	40	4110	200	1467	2372	3279	3.9
Tunnel (mouth)	11.07	150	1.0	40	4110	0	1332	2716	3740	4.4
White (mouth)	2.98	157	1.0	52	3900	1000	1940	753	1042	0.8
Wilson (well field)	116.00	150	2.0	46	4500	0	1458	16897	23580	104.1
Wilson (mouth)	189.90	150	2.0	46	4500	0	1458	26305	36818	196.7

Where: Area = Area of drainage basin (mi^2)
PPT = Mean annual precipitation (inches)
Percent Lakes = Percent of basin in main channel lakes + 1 percent
C = Continental influence (Distance to Dixon entrance in a due south direction (mi)
EMAX = maximum elevation in basin (ft)
EMIN = minimum elevation in basin (ft)
EAVG = average elevation in basin (ft)
= EMIN + 0.324 (EMAX - EMIN)
Q10 = 10-year peak flow (cfs)
$= (19.8)\ (PPT)^{1.15}\ (Area)^{0.898}\ (Percent\ Lakes)^{-0.352}\ (EAVG)^{-0.417}$
Q100 = 100-year peak flow (cfs)
$= (30.3)\ (PPT)^{1.06}\ (Area)^{0.904}\ (Percent\ Lakes)^{-0.359}\ (EAVG)^{-0.371}$
7Q10 = 7-day, 10-year low flow (cfs)
$= (0.0448)\ (PPT)^{0.565}\ (Area)^{1.29}\ (Percent\ Lakes)^{0.251}\ (C)^{-0.362}$

a/ Calculated according to the methodology in Forest Service (1980a).

these basins is lower than that in tributary basins such as White Creek because the tributary basins are at high elevations where precipitation is generally greater.

II. CONSTRUCTION PHASE FLOW ESTIMATES

During the construction phase of the project, flows in Beaver Creek and Tunnel Creek would be affected by construction-associated activities. Much of the change in flows would result from discharge of intercepted groundwater. Nonconsumptive use of waters for domestic purposes would not alter average annual flow but could shift flows from higher flow periods to low flow periods.

Water Body	Average	Low
Beaver Creek:		
Existing Flow in Beaver Creek at Sedimentation Pond (cfs)	24.0	0.5
Intercepted Groundwater from Mine Pit (cfs) (165 gpm max.)	0.4	0.4
Secondary Sewage Effluent (400 personnel camp x 80 gpd/person)	-	0.1
Flow During Construction (cfs)	24.4	1.0
Net Change (percent)	+2.0	+100.0
Tunnel Creek:		
Existing Flow in Tunnel Creek at Reservoir (cfs)	64	2.0
Intercepted Groundwater from Tunnels (cfs) 440 gpm from conveyor tunnels 275 gpm from tailings tunnel (1/2 of total) 715 gpm	1.6	1.6
Secondary Sewage Effluent (900 personnel camp x 80 gpd/person) (cfs)	0.1	0.1
Flow During Construction (cfs)	65.7	3.7
Net Change (percent)	+3.0	+85.0

III. FLOWS DURING PROJECT OPERATION

Changes in average annual and low flows due to project operations are summarized in Table D-4.

A. Average Annual Flow

Beaver Creek

Average annual flows in Beaver Creek would be affected by changes in watershed size due to pit development, altered runoff characteristics of disturbed areas, intercepted groundwater drainage from the pit, and surface water withdrawals for water supplies.

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TABLE D-4

SUMMARY TABLE
PERCENT CHANGES IN AVERAGE ANNUAL AND LOW FLOWS
DUE TO PROJECT OPERATIONS 1/

Stream	Average Annual Flow (percent)	7-day, 10-year Low Flow (percent)
Proposed Project		
Beaver Creek at sed. pond	-28	+20
Beaver Creek at mouth	-22	+17
Blossom River at mouth	-1	0
Hill Creek at sed. pond 2/	-4	-17
Hill Creek at mouth 2/	-3	-14
Keta River at mouth	1	-2
Tunnel Creek at res. 3/	-65	-100
Tunnel Creek at mouth	-31	-41
Wilson River at well site	-3	-34
Wilson River at mouth	-2	-18
Alternatives		
Upper Hill Creek diversion		
Hill Creek at sed. pond	-17	+21
Hill Creek at mouth	-14	+17
Raspberry Creek water supply		
Raspberry Creek at res. 3/	-100	-100
Raspberry Creek at mouth 3/	-40	-33

1/ Flows correspond to year 55 unless otherwise noted.

2/ Flows correspond to year 15.

3/ Assuming no minimum streamflows are maintained by the project.

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Approximately 60 percent of the Beaver Creek basin would be disturbed by the pit, access roads, overburden stockpiles, mine service area, and camp. In terms of hydrology impacts, these facilities can be divided into three groups with similar runoff characteristics: (1) access roads and cleared areas surrounding the mine service area, (2) the waste rock pile, and (3) the mine pit. Because the topsoil and glacial till stockpiles would be revegetated, the runoff characteristics of these areas are assumed to be the same as existing conditions.

The mine service area and access roads would exhibit a high runoff response due to lack of vegetation and compaction of the upper layers from mining equipment and transportation vehicles. Therefore, it is estimated that 90 percent of the annual precipitation would appear as direct runoff.

Since the ground surface below the waste rock pile would become compacted from the weight of the waste rock and from grading and dumping activities over the surface of the pile, infiltration through the original ground surface is assumed to be negligible. Therefore, virtually all of the precipitation falling on the waste rock pile would either run off the surface to adjacent areas or infiltrate the pile and flow through the void space to the area downstream of the pile. Based on the proposed project description, all precipitation falling into the mine pit would drain into Beaver Creek (up to year 15), or be pumped into Hill Creek (years 16-55).

Snow disposal areas in the basin may affect flow regimes in Beaver Creek. Changes to snowmelt runoff patterns would depend primarily on the aspect of the disposal area, as well as snow depth and volume. For determining hydrologic impacts, snow disposal areas were assumed to be located in the same drainage basin from which the snow was removed, and were not included in changes to average annual flows.

The mine personnel housing outfall (outfall 002) would discharge an average of 120 gpm (0.25 cfs) to Beaver Creek. In addition, discharge from the mine service area and crusher would be 25 gpm (0.06 cfs). During most of the operations period (years 16-55), the pit would drain to Hill Creek, decreasing the Beaver Creek basin size by 0.64 mi^2 by year 55, resulting in a new basin size of 1.47 mi^2.

To calculate average annual flows for the mining period, the basin was divided into areas of similar runoff characteristics, and surface runoff from each area was calculated. Groundwater intercepted by the pit and routed to a stream was added to the total flow, and water supply withdrawals were subtracted. The calculations are summarized in Table D-5.

TABLE D-5

AVERAGE ANNUAL FLOW IN BEAVER CREEK DURING THE MINING PERIOD

Stream	Source Area	Precipitation 1/ (cfs/mi²)	Runoff Coefficient	Fraction of Basin in Source Area	Total Basin Area (mi²)	Flow 2/ (cfs)
Beaver Cr. (Above Sedimentation Pond)	Mine pit	11.6	1.0	0	1.47	0
	Waste rock pile	11.6	1.0	0.50	1.47	8.5
	Mine serv. fac.	11.6	0.9	0.04	1.47	0.6
	Sediment. pond	11.6	1.0	0.05	1.47	0.9
	Natural areas	11.6	0.97	0.41	1.47	6.8
	Groundwater intercepted by pit					0
	Discharge from waste treatment plants					+0.3
	Water supply withdrawals					0.0
	Total					17.1

Beaver Creek	At Sedimentation Pond	At Mouth
Existing ave. flow (cfs) 3/	23.6	28.9
Mining period flow (cfs)	17.1	22.4 4/
Net change (cfs)	-6.5	-6.5
Percent change	-28 percent	-22 percent

1/ 157 inches of precipitation over the watershed = 11.6 cfs/mi².
2/ Flow = (precipitation)(runoff coefficient)(fraction of basin in source area) (total basin area).
3/ Existing flow = original basin size (mi²) x 11.2 cfs/mi².
4/ The flow at the mouth during the mining period is equal to the existing flow at the mouth plus the net change at the sedimentation pond.

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Blossom River

Blossom River flows would potentially be affected by changes in Beaver Creek flows. The existing average flow at the mouth of the Blossom River is 831 cfs. Average annual flow in Beaver Creek would decrease a maximum of 4.9 cfs. At the mouth of the Blossom River, this represents (-4.9/831) 100 = -1 percent.

Blossom River flows near the confluence with the Wilson would be affected by withdrawals of up to 36 cfs from the Blossom River intake facilities. This would primarily affect areas downstream of the confluence of the Blossom and Wilson rivers. It is anticipated that any potential downstream effects resulting from withdrawals would be negated by tidal influence, which is estimated to affect the area at least as far upstream as the intake, and by flows of the Wilson River.

Hill Creek

Average annual flow in the Hill Creek basin would be affected by the mine pit, the waste rock pile, and snow disposal areas. No water withdrawals are planned for this basin. Impacts to Hill Creek average annual flow were calculated assuming the same runoff characteristics for the pit and waste rock pile as were defined for the Beaver Creek basin.

At year 6, the pit would drain to Beaver Creek, decreasing the Hill Creek basin by 0.56 mi^2. At year 55, the pit would drain to Hill Creek, increasing the Hill Creek basin by 0.64 mi^2. Groundwater intercepted by the pit and routed to Hill Creek would be approximately 2.7 cfs at this time. Calculations for Hill Creek average annual flow are summarized in Table D-6. Average flows are calculated for both year 15 and year 55 because the lowest average annual flow for Hill Creek would occur in year 15.

Keta River

Keta River flows would be affected by changes in Hill Creek flows. The existing average flow at the mouth of the Keta River is 891 cfs. Average annual flow in Hill Creek would change a maximum of 11.6 cfs. At the mouth of the Keta River, this represents (11.6/891) 100 = +1 percent. At year 15 with a decrease in flow in Hill Creek of 5.3 cfs, flow at the mouth of the Keta River would be changed less than 1 percent.

Tunnel Creek

Approximately 36 cfs would be withdrawn from Tunnel Creek (when sufficient water is available) for the processing plant. The percentage of natural flow that this 36 cfs reduction represents is shown in Table D-7 by month.

TABLE D-6

AVERAGE ANNUAL FLOW IN HILL CREEK DURING THE MINING PERIOD

Year	Stream	Source Area	Precipitation (cfs/mi^2)	Runoff Coefficient	Fraction of Basin in Source Area	Total Basin Area (mi^2)	Flow (cfs)
6	Hill Cr. (at sed. pond)	Mine pit	11.6	1.0	0	11.65	0
		Waste rock pile	11.6	1.0	0.08	11.65	10.8
		Sed. pond	11.6	1.0	0.01	11.65	1.4
		Natural areas	11.6	0.97	0.91	11.65	119.3
		Groundwater intercepted by pit					0
		Total					131.5
55	Hill Cr. (at sed. pond)	Mine pit	11.6	1.0	0.13	12.85	19.4
		Waste rock pile	11.6	1.0	0.11	12.85	16.4
		Sed. pond	11.6	1.0	0.01	12.85	1.5
		Natural areas	11.6	0.97	0.75	12.85	108.4
		Groundwater intercepted by pit					+2.7
		Total					148.4

Hill Creek	Year 86		Year 55	
	At Sed Pond	At Mouth	At Sed Pond	At Mouth
Existing ave. flow (cfs)	136.8	161.5	136.8	161.5
Mining period flow (cfs)	131.5	156.2	148.4	173.1
Net change (cfs)	-5.3	-5.3	+11.6	+11.6
Percent change (cfs)	-4 pct	-3 pct	+8 pct	+7 pct

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TABLE D-7

PERCENT OF MONTHLY FLOW WITHDRAWN FROM TUNNEL CREEK

Month	Existing Flow at Water Supply Res. (cfs)	Percent Removed by Project Withdrawals (36 cfs)	Existing Flow at Mouth (cfs)	Percent Removed by Project Withdrawal (36 cfs)
October	118	31	242	15
November	66	55	135	27
December	45	80	92	39
January	31	116	64	31
February	25	144	51	71
March	30	120	61	59
April	48	75	99	36
May	90	40	185	19
June	100	36	205	18
July	50	72	102	35
August	40	90	83	43
September	77	47	158	23
ANNUAL	60	60	124	29

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Wilson River

Wilson River flows would be affected by withdrawing up to 36 cfs from the Wilson River well field. This water supply is not part of the preferred supplemental water supply system. However, it is presented here as another alternative that was evaluated.

Wilson River flows downstream of the confluence with the Blossom River would be affected by withdrawing up to 36 cfs from the well field.

	At Well Site	At Mouth
Existing average annual flow (cfs)	1322	2165
Maximum water supply withdrawal (cfs)	-36	-36
Minimum mining period average flow (cfs)	1286	2129
Percent reduction	-3 pct	-2 pct

Project Alternatives

Tunnel Creek Mill with Boca de Quadra Tailings Disposal and Townsite:

Diversion of Upper Hill Creek would reduce the Hill Creek basin and increase the North Creek basin by 3.06 mi^2. Changes in average annual flow to Hill and North creeks at year 55 are summarized in Table D-8.

Tunnel Creek Mill with Wilson Arm Tailings Disposal:

No change from proposed project.

Beaver Creek Mill with Boca de Quadra Tailings Disposal:

This alternative involves building a water supply reservoir on upper Raspberry Creek. Blossom River intake facilities or the Wilson well water could also be used to supplement water obtained from Raspberry Creek. Water obtained from the supplemental water supply would be stored in the Raspberry Creek reservoir prior to being used in the processing plant. Process demands exceed streamflow upstream of the Raspberry Creek reservoir for all months of the year. Average annual streamflow at the mouth of Raspberry Creek would be reduced from 35 to 21 cfs, or 40 percent from natural conditions, if all available water were withdrawn from the Raspberry Creek reservoir.

Beaver Creek Mill with On-Land Tailings Disposal:

The hydrologic regimes of Tunnel and Aronitz creeks would be essentially destroyed. The spillway and decant outlet of the Tunnel Creek impoundment is located only 50 ft upstream of the mouth of Tunnel Creek. The spillway and decant outlet of the Aronitz Creek impoundment discharges directly into Boca de Quadra, thereby dewatering the remaining 1 mi of streambed. Streamflows for all other streams would be the same as for the proposed project.

TABLE D-8

CHANGES IN AVERAGE ANNUAL FLOW AT YEAR 55
WITH UPPER HILL CREEK DIVERSION

	At Hill Creek Sedimentation Pond	At Hill Creek Mouth	At North Creek Mouth
Ave. annual flow with proposed project (no diversion) (cfs)	148.4	173.1	20.0
Ave. annual flow lost or gained from diversion (cfs)	-34.3	-34.3	+34.3
Net ave. annual flow (cfs)	114.1	138.8	54.3
Existing ave. annual flow (cfs)	136.8	161.5	20.0
Net change from existing flow (cfs)	-22.7	-22.7	+34.3
Percent change	-17 percent	-14 percent	+172 percent

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North Meadow Mill with Boca de Quadra Tailings Disposal:

Approximately 36 cfs would be withdrawn from the upper Hill Creek reservoir and sedimentation pond. The average annual flow of upper Hill Creek at the reservoir site is 34 cfs; average monthly flows are shown in Table D-2. The percent of natural flow that a 36 cfs withdrawal represents is shown by month in Table D-9.

Keta River average annual flow would be reduced 36 cfs in addition to the change caused by the proposed project (up to 5.3 cfs reduction at year 15). The net change at the Keta River mouth would be [-(36 + 5.3/891)] (100) = -5 percent.

North Meadow Mill with On-Land Tailings Disposal:

Changes in Beaver and Hill creek and Blossom, Keta, and Wilson river streamflows would be the same as for the previous alternative. Changes in Tunnel and Aronitz creek streamflows would be the same as those previously discussed for on-land tailings disposal.

B. Low Flows

Extremely low flows generally occur after extended periods of no precipitation, when nearly all of the streamflow is derived from groundwater (commonly referred to as base flow). Since the hydraulic conductivity of unconsolidated surficial deposits, including soil and glacial deposits, is much greater than that of the bedrock (see Section 3.1.4), all groundwater contributing to base streamflow was assumed to originate from the unconsolidated surficial deposits. Bedrock was assumed to make no contribution to base flow. Construction of project facilities such as the pit, mine service and housing facilities, access roads, and sedimentation ponds and dams is assumed to essentially eliminate the base flow contributions of the underlying surficial deposits in these areas. The waste rock dumps would eliminate the base flow contributions of the underlying surficial deposits by compaction, but the waste rock dumps were assumed to provide compensating base flow from groundwater storage within the void space of the waste rock. The reduction in low flow resulting from project impacts was assumed to be a function of the areas of the basin contributing to the low flow before and after project construction. The base flow reduction was calculated according to the following formula:

$$\%Q_{BR} = \frac{A_R}{A_T} \times 7Q10$$

where $\%Q_{BR}$ = reduction in base flow as a result of project development (cfs).

A_R = area of surficial deposits from which base flow contributions are assumed to be eliminated. Does not include waste rock dump areas (mi^2).

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TABLE D-9

PERCENT OF MONTHLY FLOW WITHDRAWN FROM HILL CREEK
WITH UPPER HILL CREEK RESERVOIR

Month	Natural Flow at Hill Creek Sedimentation Pond (cfs)	Percent Removed by Project Withdrawals (36 cfs)	Natural Flow at Hill Creek Mouth (cfs)	Percent Removed by Project Withdrawal (36 cfs)
October	267	13	316	11
November	149	24	176	20
December	101	36	120	30
January	71	51	84	43
February	56	64	66	55
March	67	54	79	46
April	109	33	128	28
May	204	18	241	15
June	226	16	267	13
July	112	32	133	27
August	92	39	108	33
September	175	21	206	17
ANNUAL	137	26	162	22

A_T = total area of surficial deposits in the drainage basin. Includes all soil types except Rocky Mountain Terrain. Areas taken from Figure 3-2.

7Q10 = 7-day, 10-yr low flow under existing conditions (cfs).

Mining phase low flows were then calculated by subtracting the base flow reduction and water supply withdrawals from existing 7-day, 10-yr low flows, and adding the discharges from the waste treatment plant and drainage from the mine pit, if any. (All groundwater intercepted by the pit and routed to Beaver or Hill creeks is assumed to represent deep groundwater that would not normally reach these streams. This water therefore represents an addition to flow as compared to existing conditions.) These calculations are summarized below for all project area streams. Low flows for Hill Creek were calculated for both year 15 and year 55 because the minimum levels occur at year 15. Minimum flows at Beaver Creek occur at year 55.

Beaver Creek - Year 55

Mining phase 7-day, 10-yr low flow above sedimentation pond:

Existing 7-day, 10-yr low flow 1/	0.5 cfs
Base flow reduction = [(0.63 mi^2/1.76 mi^2)](0.5 cfs) =	-0.2
Waste treatment plant discharge 2/	0.3
Water supply withdrawals	0.0
Groundwater intercepted by pit (pit drains to Hill Creek)	0.0

Total
0.6 cfs

Summary - Beaver Creek

	At Sed Pond	At Mouth
Existing 7-day, 10-yr low flow (cfs) 1/	0.5	0.6
Mining phase 7-day, 10-yr low flow (cfs)	0.6	0.7
Net change (cfs)	+0.1	+0.1
Percent Change	20 pct	17 pct

Blossom River near Mouth (upstream of intake facilities)3/

Beaver Creek flows would be increased a maximum of 0.1 cfs.

Existing 7-day, 10-yr low flow	48.0 cfs
Reduction from Beaver Creek	0.1
Mining phase flow	48.1
Percent change = 0.1/48.0	0.2 pct

1/ See Table D-3.
2/ 47 gpm = 0.1 cfs.
3/ See Wilson River alternative "at mouth" for effects of potential 35.6 cfs withdrawal.

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Hill Creek

Mining phase low flow at sedimentation pond (year 6):

Existing 7-day, 10-yr low flow	4.8 cfs
Baseflow reduction = [(0.92 mi^2/5.78 mi^2)]/(4.8 cfs) =	-0.8
Groundwater intercepted by pit	0.0
Total	4.0 cfs

Mining phase low flow at sedimentation pond (year 55):

Existing 7-day, 10-yr low flow	4.8 cfs
Base flow reduction [(0.92 mi^2/5.78 mi^2)](4.8 cfs) =	-0.8
Groundwater intercepted by pit	+2.7
Total	6.7 cfs

Summary - Hill Creek

Hill Creek	Year 5 At Sed Pond	Year 5 At Mouth	Year 55 At Sed Pond	Year 55 At Mouth
Existing low flow (cfs)	4.8	5.8	4.8	5.8
Mining phase low flow (cfs)	4.0	5.0	6.7	7.7
Net change (cfs)	-0.8	-0.8	+1.9	+1.9
Percent change (cfs)	-17 pct	-14 pct	+40 pct	+33 pct

Keta River at Mouth

Hill Creek flows would be reduced a maximum of 0.8 cfs.

Existing 7-day, 10-yr low flow	52.6 cfs
Reduction from Hill Creek	-0.8
Mining phase flow	51.8
Percent change = 0.8/52.6	-1.5 pct

Tunnel Creek

Immediately below reservoir:

Low flows are dependent on minimum streamflows maintained by the project that have not yet been defined. Without minimum flows, the 7-day, 10-yr low flow would be reduced to zero.

Above mouth:

Streamflow contributed from the area between the mouth and the reservoir equals the natural flow at the mouth minus the natural

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flow at the reservoir or 4.4 - 1.8 = 2.6 cfs. This water would represent the only flow at the mouth if no water were released from the reservoir.

Net low flow at mouth = 2.6 cfs
Percent reduction = (2.6-4.4)/4.4 = -0.41 or 41 percent reduction

Wilson River Alternative

Immediately below wells:

Existing 7-day, 10-yr low flow	104.1 cfs
Maximum possible water supply withdrawals 1/	-35.6
Mining phase flow	68.5

Percent change = (68.5-104.1)/104.1 = -0.34 or 34 percent reduction

At Mouth:

Existing 7-day, 10-yr low flow	196.7 cfs
Maximum possible water supply withdrawals	-35.6
Mining phase flow	161.1

Percent change = (161.1-196.7)/196.7 = -0.18 or 18 percent reduction

Upper Hill Creek Diversion Alternative

Hill Creek would be diverted just above the ultimate upper end of the waste rock disposal area after year 5 (when pit drainage is routed to Hill Creek).

Year 55	Sedimentation Pond	Mouth
Low flow without diversion (cfs) 2/	6.7	7.7
Flow lost from diversion (cfs) 3/	-0.8	-0.8
Net flow (cfs)	5.9	6.9
Existing low flow (cfs)	4.8	5.8
Net change (cfs)	+1.1	+1.1
Percent change	+23 pct	+19 pct

Raspberry Creek Reservoir

Immediately below reservoir:

Without minimum flows, net flow would = 0 (100 percent reduction)

1/ 16,000 gpm = 35.6 cfs.
2/ This flow is the mining phase 7-day, 10-yr low flow of the proposed project.
3/ Natural 7-day, 10-yr low flow at Hill Creek (reservoir) from Table D-3.

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At mouth:

Existing 7-day, 10-yr low flow = 0.9 cfs
With reservoir and no minimum streamflow, low flow = 0.9-0.3 = 0.6 cfs or a 33 percent reduction.

IV. POSTMINING PERIOD

After mining operations cease, the pit area would no longer be dewatered and would gradually fill with water. During the period that the pit is filling, precipitation falling on the pit area and groundwater intercepted by the pit would not be discharged to Hill Creek. The following assumptions were made in calculating Hill Creek flows during this period.

1) Runoff from areas above the pit is diverted away from the pit and therefore does not aid in filling the pit.

2) Forty percent of the material removed from the pit during mining is below the ultimate water level of the pit.

The volume of water contained in the pit when full:

Amount of ore, waste rock, and overburden removed = 2.3×10^9 tons
Assumed density = 2.65 ($62.4\ lb/ft^3$) = $165\ lb/ft^3$

$$\text{Volume of pit} = \frac{(2.3\times10^{9}\ \text{tons})(2000\ \text{lb/ton})}{165\ \text{lb/ft}^3} = 2.8\times10^{10}\ \text{ft}^3$$

Volume below ultimate pit water level = $0.40(2.8 \times 10^{10}\ ft^3)$ = $1.12 \times 10^{10}\ ft^3$

Rate of inflow to the pit:

Inflow = precipitation + groundwater

$= (190\ in/yr)(1.67\ mi^2)(640\ ac/mi^2)(43{,}560\ ft^2/ac)(1\ ft/12\ in)$
$+ (2.7\ ft^3/s)\ (3{,}600\ s/hr)(24\ hr/day)\ (365\ day/yr)$
$= 7.37 \times 10^8\ ft^3/yr + 0.85 \times 10^8\ ft^3/yr$

Pit Inflow = $8.22 \times 10^8\ ft^3/yr$

Duration of pit filling:

$$\text{Yrs to fill pit} = \frac{1.12\times10^{10}\ \text{ft}^3}{8.22\times10^{8}\ \text{ft}^3/\text{yr}} = 13.6 \text{ yrs or approx. 14 yrs}$$

Hill Creek Average Annual Flow During Period of Pit Filling

Hill Creek above sedimentation pond (based on Table D-6, year 55):

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Mine pit	0.0 cfs	(no discharge from pit runoff)
Waste rock pile	16.4 cfs	
Sedimentation pond	1.5 cfs	
Natural areas	108.4 cfs	
Groundwater intercepted by pit	0.0 cfs	(trapped in pit until full)
TOTAL	126.3 cfs	

Percent change from existing flow:

	At Sedimentation Pond	At Mouth
Existing average flow (cfs)	136.8	161.5
Reclamation flow (during pit filling) (cfs)	126.3	151.0
Net change (cfs)	-10.5	-10.5
Percent Change	-8 percent	-7 percent

Hill Creek with upper hill creek diversion (from Table D-8):

	At Sedimentation Pond	At Mouth
Average annual flow with no diversion (cfs)	126.3	151.0
Average annual flow lost from diversion (cfs)	-34.3	-34.3
Net average annual flow (cfs)	92.0	116.7
Existing average annual flow (cfs)	136.8	161.5
Net change (cfs)	-44.8	-44.8
Percent change	-33 percent	-28 percent

Hill Creek Low Flow During Period of Pit Filling

Hill Creek above sedimentation pond (based on calculations for Hill Creek low flow):

Existing 7-day, 10-year low flow	4.8 cfs	
Base flow reduction	-0.8	
Groundwater intercepted by pit	0.0	(does not discharge until pit fills)
	4.0 cfs	

Percent change from existing flow:

	At Sedimentation Pond	At Mouth
Existing low flow (cfs)	4.8	5.8
Reclamation (during pit filling flow) (cfs)	4.0	5.0
Net change (cfs)	-0.8	-0.8
Percent change	-20 percent	-16 percent

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Hill Creek Above Sedimentation Pond with Upper Hill Creek Diversion:

	At Sedimentation Pond	At Mouth
Low flow without diversion	4.0	5.0
Flow lost from diversion	-0.8	-0.8
Net flow	3.2	4.2
Existing low flow	4.8	5.8
Net change	-1.6	-1.6
Percent change	-33 percent	-28 percent

After the pit has filled with water and revegetation is complete, it is assumed that all disturbed areas would have a runoff coefficient similar to natural conditions, resulting in average streamflows equivalent to 11.4 cfs/mi^2 (Blossom, Keta, and Wilson rivers) or 11.2 cfs (all other streams). Streamflows of all streams except Beaver and Hill creeks would be the same as existing flows. Changes in average annual streamflow in Beaver and Hill creeks would be proportional to changes in basin size.

Beaver Creek Basin

The Beaver Creek basin would be reduced by 0.64 mi^2 due to the pit draining to Hill Creek.

At sedimentation pond:

Original size = 2.11 mi^2
Percent change = (0.64/2.11) (100) = 30 percent reduction

At mouth:

Original size = 2.58 mi^2
Percent change = (0.64/2.58) (100) = 25 percent reduction

Blossom River

At mouth:

Original size = 72.8 mi^2
Percent change = (0.64/72.8) (100) = less than 1 percent reduction

Hill Creek Basin

The Hill Creek basin would be increased by 0.64 mi^2.

At sedimentation pond:

Original size = 12.21 mi^2
Percent change = (0.64/12.21) (100) = 5 percent increase

At mouth:

Original size = 14.42
Percent change = (0.64/14.42) (100) = 4 percent increase

<u>Keta River</u>

At mouth:

Original size = 78.2 mi^2
Percent reduction = (0.64/78.2) (100) = less than 1 percent increase

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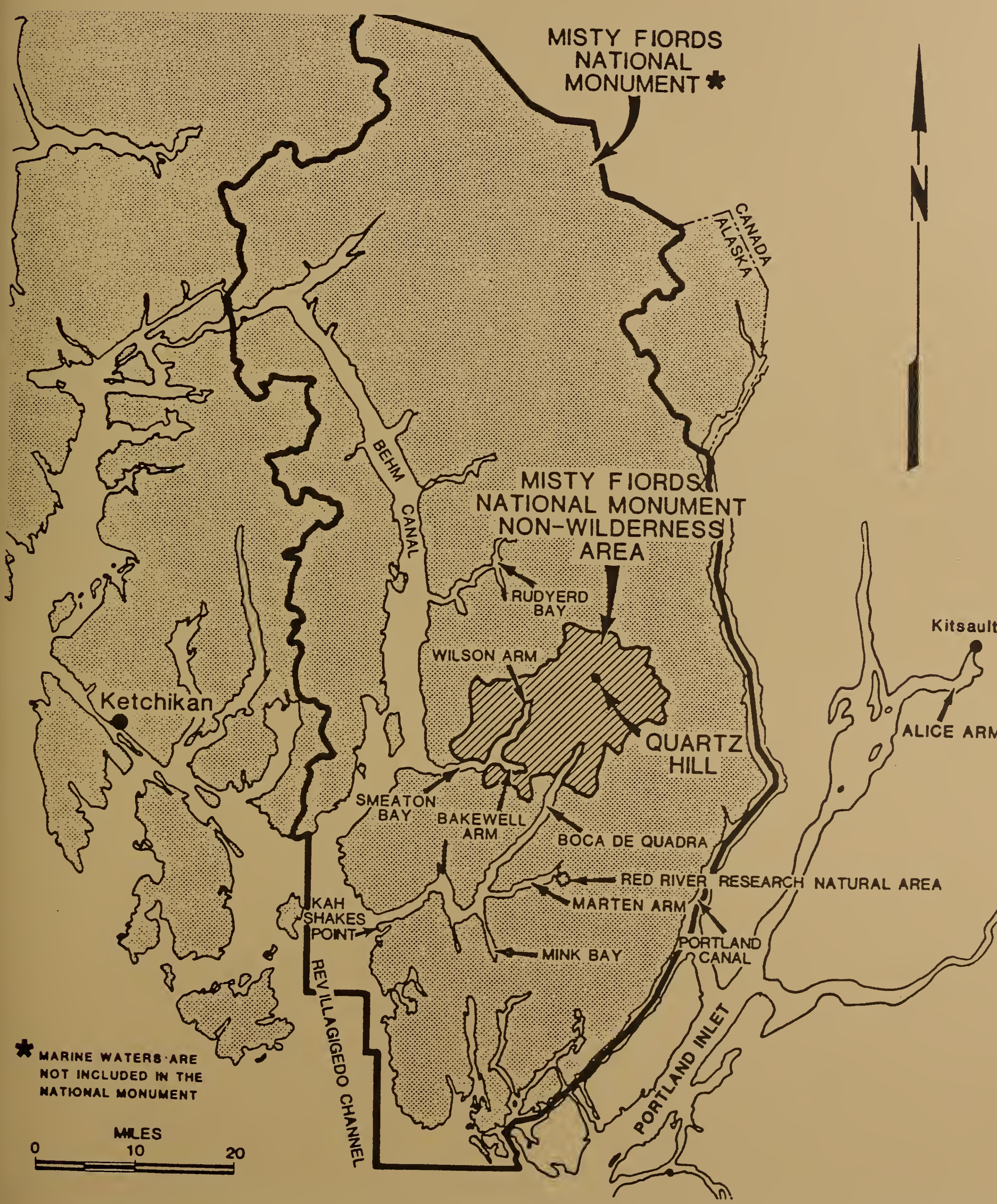
APPENDIX E
WATER QUALITY



APPENDIX E - WATER QUALITY

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I. METHOD FOR CALCULATING INCREASED SEDIMENT LOADS INTO PROJECT WATER BODIES DUE TO PROJECT CONSTRUCTION AND OPERATION

A. CONSTRUCTION PHASE

Assumptions

- Sediment contributions from landslides caused by widening the Blossom River access road from 14 to 36 ft will be approximately equal to the sediment contributions caused by construction of the original road as determined by Lyons (1984).

- Construction-induced landslides into the Keta River will contribute 21 percent of the predicted sediment loading (Forest Service 1982a) based on observations and estimates of landslide sediment during the construction of the Blossom River access road (Lyons 1984).

- Sediment contribution to waterways from roadbed erosion during construction will be one-half the annual estimated loading during project operation, based on an average road length of one-half the finished length.

- U.S. Borax will adhere to erosion and landslide control measures similar to those that are required by the current U.S. Forest Service Special Use Permit for Access Road Construction. Pertinent sections of this special use permit are listed in Table I-1 of this appendix.

- The ambient sediment load for Blossom River is 19,850 tons/yr, and for Keta River, 23,000 tons/yr (Forest Service 1984a). The ambient sediment load for Wilson River is estimated to be 283 tons/mi^2/yr, based on the Blossom River and Keta River data. (VTN [1984] estimated ambient loads of 34,000 tons/yr for Blossom River and 31,400 tons/yr for Keta River. Use of these higher values reduces sediment increases by 40 percent for Blossom River, 35 percent for Wilson River, and 25 percent for Keta River.)

- The dry weight soil density is 45 lb/ft^3 (Forest Service 1982a).

- The weight fraction of landslide soil material smaller than 2.0 mm diameter averages 52 percent (Forest Service 1982a). Only this size fraction of the landslide material will be transported as suspended sediment in the rivers.

Below is a sample calculation of suspended sediment loading from landslides for the Blossom River.

Landslide material = 242,000 lb (Lyons 1984)
Dry weight density = 45 lb/ft^3
Weight fraction of transportable material <2.0 mm = 0.52
Weight conversion, 1 ton = 2000 lb

$$(242{,}000\ \text{ft}^3) \times (45\ \text{lb/ft}^3) \times (0.52\ \text{lb/lb}) \times 1\ \text{ton}/2000\ \text{lb} = 2830\ \text{tons}$$

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TABLE I-1

EXCERPTS FROM THE U.S. FOREST SERVICE SPECIAL USE PERMIT FOR CONSTRUCTION OF THE BULK SAMPLING ROAD (FOREST SERVICE 1982d)

---

1. During periods of high rainfall when soils are becoming water saturated, it is the intent of the Forest Service to restrict or suspend blasting operations in high slide potential areas. Two approved hourly recording rain gauges shall be installed and maintained by the permittee in an agreed location in the Raspberry Creek meadows and the fuel cache. Data derived from these rain gauges will be used as a guide in determining when the soils are becoming water saturated.

2. It is intended that the permittee shall confine excavated material within the roadway limits. The nature of the project area dictates that special construction techniques are required to accomplish this intent. In the event that excavated material becomes deposited outside of the roadway limits, particularly the lower fill stake, the permittee, if directed by the Forest Service representative, shall remove this material and incorporate it into designated areas. Removal of this material shall begin immediately when required for environmental concerns such as streamcourse protection or sensitive slopes or when directed by the Forest Service representative.

3. Drainage Structures:

    a. Site plans required for all fish stream culverts and all bridges.

    b. All live stream and fish stream culverts to be designed to pass a 20 year storm.

    c. Energy dissipators will be considered for all culverts unless otherwise agreed. Energy dissipators may include such measures as shot rock placed at the discharge end of the culvert.

    d. During construction, particularly during subgrading operations, temporary drainage shall be continuously provided. Drainage shall be directed to concentrate water only in natural drainage channels to avoid overburdening slopes.

A summary of construction-related sediment load increases is presented in Table I-2.

B. MINING PERIOD

Assumptions

- o Ambient sediment loads are assumed to be 283 tons/mi^2/yr (Forest Service 1984).

- o Upper bounds of sediment production from roads in the project area are assumed to be similar to those calculated for logging roads in the Olympic Peninsula, and presented in Reid (1981) and Cederholm et al. (1981). These values were considered valid because rainfall intensity, amounts, and patterns in the project area are very similar to those in the Olympic Peninsula (U.S. Dept. of Commerce 1961, 1963). Therefore, erosivity potential of the two areas should be very similar. Sediment production values of Reid (1981) are considered "worst case" because the roads in the Olympic Peninsula study generally consisted of gravel over fine-grain substrate, whereas project roads will generally be gravel over a coarser substrate. Sediment eroded from the project roads will generally be from crushing of the gravel material, not from the substrate.

  Road use was assumed to be "moderate," defined in Reid (1981) as one to four logging trucks per day, "five days per week." Road use of the project roads will generally be much higher than four vehicles a day, but will consist of lighter vehicles. Therefore, moderate use was considered to be appropriate for the project access roads.

- o All sediment eroded from roads is assumed to be washed into a roadside ditch.

- o All sediment from the ditches is assumed to eventually reach a stream because ditches will not be periodically cleaned.

- o All sediment reaching tributary streams will eventually reach the main stream because gradients in the tributary streams are relatively high, precluding significant sediment deposition.

- o All tailings pipeline routes will be revegetated, resulting in negligible long-term sediment contributions.

- o Sediment pond effluents will contribute a negligible amount to total sediment load because suspended solids concentrations will average less than 30 mg/l.

- o All sediment reaching the Blossom River will eventually reach the lower Wilson River, because it is assumed that no net accumulation of sediment will occur in the Blossom River.

TABLE I-2
CONSTRUCTION PHASE SEDIMENT LOAD INCREASES

Water Body	Basin Size (mi^2)	Natural Sediment Load (tons/yr)	Road-Induced Sediment from Landslides (tons/yr)	Erosion During Construction (tons/yr)	Percent Increase
Blossom River (Alternatives 2-7) 1/	72.9	19,850	2,830	640	17
Wilson River 2/ (Alternatives 2-7)	186 3/	52,630	2,830 4/	915	7.1
Keta River (Alternatives 8, 9)	78.2	23,000	380-450 5/	880	5.5-5.8

1/ The alternative numbers correspond to those in Table I-3.

2/ Below confluence with Blossom River.

3/ The basin site corresponds to the area downstream of Wilson Lake because the lake is assumed to trap nearly all upstream sediment.

4/ All sediment reaching the Blossom River will eventually reach the lower Wilson River because it is assumed that no net accumulation of sediment will occur in the Blossom River.

5/ This range of values reflects the low and high sediment loading estimates by the Forest Service 1982a.

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Calculations of Roadbed Erosion

From Reid (1981) Table 13: Road surface erosion from moderate use roads = 100 metric tons/(hectare of road)/yr. The equation is based on data samples taken at points equivalent to points of discharge into waterways. Sediment removal by roadside gravel is inherent in the data.

$$(100 \text{ m tons/ha-yr})(1.10 \text{ tons/m ton})(1 \text{ ha}/1.076 \times 10^5 \text{ft}^2)(5280 \text{ ft/mi}) = 5.41 \text{ tons/ft-mi-yr}$$

or

$$(100 \text{ m tons/ha-yr})\ (1.10 \text{ tons/m ton})\ (1 \text{ ha}/0.405 \text{ ac}) = 44.6 \text{ tons/(acre of road)/yr}$$

Roadbed erosion is presented by project access road or facility in Table I-3, and for each alternative project concept in Table I-4.

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TABLE I-3

SEDIMENT CONTRIBUTIONS TO PROJECT WATER BODIES
BY PROJECT ACCESS ROAD OR FACILITY
MINING PERIOD

Project Alternative 1/	Access Road or Facility	Water Body Affected	Basin Size (mi^2)	Natural Sediment Load (tons/yr) 2/	Road Length in Basin (mi)	Road Width (ft)	Road-Related Sediment Load (tons/yr) 3/	Percent Increase 4/
2-7	Blossom Access Road	Blossom River	72.9	19,850	6.6	36	1,285	6.5
		Wilson River	113 5/	31,980	7.1	36	1,383	4.3
		Wilson Arm	144	40,750	9.4	36	1,831	4.5
2-7	Access Road to Blossom River Supplemental Water Intake Facility	Wilson River	113	31,980	0.6	14	45	<1
		Wilson Arm	144	40,750	0.6	14	45	<1
2-4	Tunnel Creek Access Road	Tunnel Creek	11.07	3,130	2.0	36	390	12.5
		Wilson Arm	144	40,750	2.0	36	390	<1
2-7	Dock on Wilson Arm	Wilson Arm	144	40,750	(9 ac)		401	<1
2, 3	Access Road from Tunnel Adit on Boca de Quadra to Wharf	Boca de Quadra	148 6/	41,880	0.4	14	30	<1
3	Access Road to Bakewell Townsite from Blossom Access Road	Wilson Arm	144	40,750	9	36	1,753	4.3
4	Blossom Access Road, Longer Road to Tailings Outfall	Wilson Arm	144	40,750	12.4	36	2,415	5.9
7	Access Road from Tailings Dam on Aronitz Creek to Wharf on Boca de Quadra	Boca de Quadra	148	41,880	1.0	14	76	<1
8, 9	Keta Access Road	Keta River	78.2	23,000	9.0	36	1,753	7.6
		Boca de Quadra	148	41,880	10.0	36	1,948	4.6

1/ Alternative numbers correspond to those in Table I-2.
2/ Natural sediment load = basin size x 283 tons/mi^2/yr.
3/ Road sediment = 5.41 x road length x road width or 44.6 tons/acre x facility size.
4/ If the ambient sediment load is assumed to be 423 ton/mi^2/yr as stated in VTN (1984, p. 5) instead of 283 tons/mi^2/yr as used here, all percentage increases listed in this column would be lower by approximately one-third.
5/ The basin size of the Wilson River corresponds to the area downstream of Wilson Lake because it is assumed Wilson Lake traps nearly all sediment flowing into it from upstream areas.
6/ Upstream of the confluence with Marten Arm.

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TABLE I-4
SEDIMENT CONTRIBUTIONS TO PROJECT
WATER BODIES BY PROJECT CONCEPT (tons/year)
OPERATION PERIOD

Water Body	No Action	Project Alternative 1/ 2	3	4	5	6	7	8	9
Blossom River	-	1285	1285	1285	1285	1285	1285	-	-
percent increase		6	6	6	6	6	6		
Tunnel Creek	-	390	390	390	-	-	-	-	-
percent increase		13	13	13					
Wilson River	-	1428	1428	1428	1428	1428	1428	-	-
percent increase		4	4	4	4	4	4		
Wilson Arm 2/		2667	4420	3251	2277	2277	2277	-	-
percent increase		7	11	7	6	6	6		
Keta River	-	-	-	-	-	-	-	1753	1753
percent increase								7	7
Boca de Quadra		30	30	-	-	-	76	1948	1948
percent increase		<1	<1	-	-	-	<1	4	4

1/

Alternative	Project Concept	Alternative	Project Concept
1	No Action	6	Beaver Creek mill with Wilson Arm tailings disposal
2	Tunnel Creek mill with Boca de Quadra tailings disposal		
3	Tunnel Creek mill with Boca de Quadra tailings disposal and townsites	7	Beaver Creek mill with on-land tailings disposal
4	Tunnel Creek mill with Wilson Arm tailings disposal	8	North Meadow mill with Boca de Quadra tailings disposal (Keta alternative)
5	Beaver Creek mill with Boca de Quadra tailings disposal	9	North Meadow mill with on-land tailings disposal

2/ Wilson Arm contributions include sediment from access roads in the Tunnel Creek and Blossom River basins and roads and facilities located adjacent to Wilson Arm.

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A. FEDERAL EFFLUENT LIMITATIONS

U.S. Borax has committed to meeting Federal effluent limitations at the point of discharge from their water quality control facilities. These discharges are regulated under the Clean Water Act as mining and dressing point sources and require NPDES permits. The effluent limitations applicable to Quartz Hill are the New Source Performance Standards (NSPS) for drainage from mines producing molybdenum-bearing ores from an open-pit published in the Federal Register (Vol. 47, No. 233, December 3, 1982). Even though this project was specifically excluded from this rulemaking, the established limitations are presented below and in Table III-8 to provide compliance levels for comparison and evaluation of impacts.

Section 440.104 - New Source Performance Standards (NSPS)

"a. The concentration of pollutants discharged in mine drainage from mines that produce copper, lead, zinc, gold, silver, or molybdenum-bearing ores or any combination of these ores from open-pit or underground operations other than placer deposits shall not exceed:

Effluent Characteristic	Effluent Limitations: Maximum for Any 1 Day	Effluent Limitations: Average of Daily Values For 30 Consecutive Days
	Milligrams Per Liter	
Cu	0.30	0.15
Zn	1.5	0.75
Pb	0.6	0.3
Hg	0.002	0.001
Cd	0.10	0.05
pH	(1)	(1)
TSS	30.0	20.0

(1) Within the range of 6.0 to 9.0."

B. PROPOSED ALASKA RECEIVING WATER QUALITY STANDARDS

U.S. Borax has committed to meeting Alaska Receiving Water Quality Standards at the boundaries of approved mixing zones downstream from their water quality control facilities. State water quality standards have been established to protect the use of the water by use

classifications (18 AAC 70.020). Because the streams in the Quartz Hill project area have not been assigned a special use classification by the ADEC, the streams are subject to the strictest standards associated with all of the use classes (18 AAC 70.030) (Hayden 1983; Haavig 1984). The strictest standard for each water quality parameter was therefore selected from among the freshwater use classifications and are presented in Table II-1. The only exception was in the case of parameter (7) sediment, where the standard for Class 1C was presented instead of the stricter standard for Class IA per a specific request in EPA's review comments and recommendations of the PDEIS, January 6, 1984. The numerical values for these standards are presented in Table II-2.

For parameter (8) toxic substances, some interpretation of the standard's description was required in order to develop proposed trace metal concentrations for comparison purposes and for characterization of influent to water quality control facilities from disturbed areas. A toxic substance standard should be chosen from three different criteria sources; specifically:

> "Substances shall not individually or in combination exceed 0.01 times the lowest measured 96-hr LC_{50} for life stages of species identified by the department as being the most sensitive, biologically important to the location, or exceed criteria cited in EPA Quality Criteria for Water, or Alaska Drinking Water Standards, whichever concentration is less."

The numerical values for these three sources are presented in Table II-2. The first source was excluded from further consideration due to lack of specific bioassay results. The EPA water quality criteria, as revised in 1985-87, are listed. For these revised criteria, the first value labeled "1-hr ave" represents the acute toxicity level, and the second value, "4-day ave," represents the chronic toxicity level. The majority of these trace metal concentrations are developed from equations that take into account the hardness of the water, because a given concentration of metal becomes more toxic as the hardness of the water decreases. The third criteria source, Alaska Drinking Water Standards, are summarized for the trace metals from Table II-3.

From these sources the lowest concentration should be selected as the proposed standard. The ADEC suggested using the Drinking Water Standard if it was the lowest; but agreed that since the receiving waters in the project area are not going to be used as a source for drinking water and because these standards were originally developed for public water supply systems, applying these standards to Quartz Hill sedimentation pond discharge could be viewed as unreasonable (Haavig 1984). Therefore, the EPA water quality criteria were used as the proposed Alaska Receiving Water Quality Standards in the modeling efforts. The ADEC does indicate, however, that as a matter of policy and as a starting point during the actual permit negotiation process, the Drinking Water Standards may be applied (Haavig 1987). The numerical values were calculated for a hardness of 100 mg/l as $CaCO_3$, which is the approximate hardness of the resulting water below the outfalls (see Section III-E).

TABLE II-1

ALASKA RECEIVING WATER QUALITY STANDARDS
(18 AAC 70.020)

Summary of strictest water quality standards for freshwater use classes 1A, 1B, and 1C:

1. Fecal Coliform Bacteria: Based on a minimum of 5 samples taken in a period of 30 days, mean shall not exceed 20 FC/100 ml, and not more than 10 percent of the samples shall exceed 40 FC/100 ml (Class 1A[i] and 1B[i]).

2. Dissolved Oxygen: DO shall be greater than 7 mg/l in water used by anadromous and resident fish. In no case shall DO be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel utilized by anadromous or resident fish for spawning. For waters not used by anadromous or resident fish, DO shall be greater or equal to 5 mg/l. In no case shall DO above 17 mg/l be permitted. The concentration of total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection (Class 1C).

3. pH: Shall not be less than 6.5 or greater than 8.5. It shall not vary more than 0.5 pH units from natural conditions (Class 1A[i] and 1C).

   Variation in pH for waters naturally outside of the specific range should be towards the range (all classes).

4. Turbidity: Shall not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and shall not have more than a 10 percent increase in turbidity when the natural condition is more than 50 NTU, not to exceed a maximum increase of 25 NTU (Class 1A[i]).

5. Temperature: Shall not exceed 15°C at any time. The following maximum temperature shall not be exceeded, where applicable.

Migration routes	15°C
Spawning areas	13°C
Rearing areas	15°C
Egg and fry incubation	13°C

   For all other waters, the weekly average temperature shall not exceed site specific requirements needed to preserve normal species diversity or to prevent appearance of nuisance organisms (Class 1A[i], [iii], and 1C).

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6. Dissolved Inorganic Substances: Total dissolved solids shall not exceed a maximum of 1,500 mg/l including natural conditions. Increase in TDS shall not exceed one-third of the concentration of the natural condition of the body of water (Class 1A[iii] and 1C).

7. Sediment: The percent accumulation of fine sediment in the range of 0.1 mm to 4.0 mm in the gravel bed of waters utilized by anadromous or resident fish for spawning may not be increased more than 5 percent by weight over natural condition (as shown from grain size accumulation graph). In no case may the 0.1 mm to 4.0 mm fine sediment range in the gravel bed of waters utilized by anadromous or resident fish for spawning exceed a maximum of 30 percent by weight (as shown from grain size accumulation graph) (see note 3 and 4). In all other surface waters no sediment loads (suspended or deposited) which can cause adverse effects on aquatic animal or plant life, their reproduction, or habitat (Class 1C).

8. Toxic and Other Deleterious Organic and Inorganic Substances: Substances shall not individually or in combination exceed 0.01 times the lowest measured 96-hr LC_{50} for life stages of species identified by the department as being the most sensitive, biologically important to the location, or exceed criteria cited in EPA Quality Criteria for Water, or Alaska Drinking Water Standards, whichever concentration is less. Substances shall not be present or exceed concentrations which individually or in combination impart undesirable odor or taste to fish or other aquatic organisms as determined by either bioassay or organoleptic tests (Class 1C).

9. Color: Color or apparent color shall not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life. For all waters not having a seasonally established norm for aquatic life, color or apparent color shall not exceed 15 color units (Class 1B[i] and 1C).

10. Petroleum Hydrocarbons, Oils and Grease: Total hydrocarbons in the water column shall not exceed 15 μg/l or 0.01 of the lowest measured continuous flow 96-hr LC_{50} for life stages of species identified by the department as the most sensitive, biologically important species in a particular location, whichever concentration is less. Total aromatic hydrocarbons in the water column shall not exceed 10 μg/l or 0.01 of the lowest measured continuous flow 96-hr LC_{50} for life stages of species identified by the department as the most sensitive, biologically important species in a particular location, whichever concentration is less. Concentrations of hydrocarbons, animal fats, or vegetable oils in the sediment shall not cause deleterious effects to aquatic life. Shall not cause a film, sheen, or discoloration on the surface or floor of the water body or adjoining shorelines. Surface waters shall be virtually free from floating oils (Class 1C).

11. Radioactivity: Shall not exceed the concentrations specified in the Alaska Drinking Water Standards and shall not exceed (for the organisms present) the maximum permissible limits for specific radioisotopes and unidentified mixtures as established by the Title 10 Code of Federal Regulations, Part 20 and National Bureau of Standards, Handbook 69 (all classes).

12. Total Residual Chlorine: Shall not exceed 2.0 μg/l for salmonid fish or 10.0 μg/l for other organisms (Class 1A[iii] and 1C).

13. Residues (floating solids, debris, sludge, deposits, foam, scum): Shall not alone or in combination with other substances or waste cause the water to be unfit, unsafe, or cause acute or chronic problem levels as determined by bioassay or other appropriate methods. Shall not alone or in combination with other substances cause a film, sheen, or discoloration on the surface of the water or adjoining shoreline; or cause leaching of toxic or deleterious substance; or case a sludge, solid, or emulsion to be deposited beneath or upon the surface of the water, within the water column or the bottom, or upon the adjoining shorelines (Class 1C).

Source: ADEC (1982).

TABLE II-2
PROPOSED ALASKA RECEIVING WATER QUALITY STANDARDS FOR SELECTED TRACE METALS 1,2/

		EPA Water Quality Criteria 3/	
Substance	0.01 x 96-hr LC_{50}	1-hr Ave/4-Day Ave	Alaska Drinking Water Standards
Arsenic	No specific	0.360/0.190	0.05
Cadmium	species was	0.0039/0.0011	0.010
Chromium 4/	identified by	0.016/0.011	0.05
Copper	the ADEC as	0.018/0.012	1.00
Iron	being the	-/1.00	0.30
Lead	most sensitive	0.082/0.0032	0.05
Manganese	or biologically	-/-	0.05
Mercury	important to	0.0024/0.000012	0.002
Molybdenum	the location,	-/-	-
Nickel	so no species	1.4/0.16	-
Selenium	specific bioassays	0.26/0.035	0.01
Silver	for trace metals	0.0041/0.00012	0.05
Zinc	in freshwater	0.12/0.11	0.20
	were determined.		

1/ All values in mg/l.
2/ Based on a hardness of 100 mg/l as $CaCO_3$.
3/ EPA (1985, 1986, 1987).
4/ Hexavalent chromium.

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TABLE II-3

ALASKA DRINKING WATER STANDARDS
(18 AAC 80.050)

Parameter	Safe Drinking Water Act[1/] Primary Drinking Water Standards	Secondary Drinking Water Standards
Arsenic	0.05	
Barium	1.0	
Cadmium	0.010	
Chloride		500
Chromium	0.05	
Color		15 PCU
Copper		1.0
Corrosivity		relatively low
Endrin	0.0002	
Foaming agents (surfactants)		0.05
Fluoride	1.4-2.4 (temperature-dependent)	
Iron		0.3
Lead	0.05	
Lindane	0.004	
Manganese		0.05
Mercury	0.002	
Methoxychlor	0.1	
Nitrate (as N)	10.0	
Odor		3 threshold odor number
pH		6.5-8.5
Radionuclides: Gross Alpha	15 pCi/l	
Gross Beta	50 pCi/l	
Radium (226 + 228)	5 pCi/l	
Tritium	20,000 pCi/l	
Strontium	8 pCi/l	
Selenium	0.01	
Silver	0.05	
Sulfate		500
Total dissolved solids		1000
Toxaphene	0.005	
Zinc		5.0
2,4,D	0.1	
2,4,5 TP (silvex)	0.1	
Specific conductance		1600 micromhos

1/ All values in mg/l except where noted.

Source: ADEC (1982).

III. IMPACTS ON STREAM WATER QUALITY

A. DISCUSSION ON THE CHARACTERISTICS AND DISTURBANCE OF MUSKEG

Muskeg can play a major role in controlling the quantity and quality of surface water. The importance of this role is determined by the distribution and extent of muskeg in a drainage basin; the slope, porosity, and type of underlying geological material; and the predominate vegetation species.

Muskeg modifies the typical runoff characteristics of a drainage basin by providing some retention, i.e., precipitation and surface runoff is retained by the muskeg, depending on its effective storage capacity, and then slowly discharged later to provide a portion of the base flow.

Muskeg can modify the surface water quality in the following ways:

1. Filters out suspended sediments during normal flow conditions (Mayhood and Corkum 1981)

2. During periods of active photosynthesis, muskeg takes up nutrients and CO_2 from the incoming waters and releases oxygen (Akena 1979, p. 56-77)

3. During periods of decomposition, muskeg releases nutrients, organic carbon, and humic acids, which increase the turbidity and color of the discharged water; decreases the DO due to increased BOD and reduced photosynthesis (Akena 1979, p. 56-77)

4. Increases acidity due to the oxidation of organic sulfur compounds in the peat (Walmsley 1977, p. 95)

5. Adsorbs heavy metals by cation exchange on organic colloids such as lignins at pHs between 3.0 and 8.0 (Akena 1979, p. 157).

An extensive search of the literature on muskeg revealed a great deal of information on the characterization of muskeg and its role in the hydrology of a drainage basin, and some recent information obtained on water quality, but no documented information on how the disturbance of a muskeg area would affect downstream water quality. The one specific discussion on muskeg disturbance that was found (Schwartz and Milne-Howe 1982) proposes that changes in downstream water quality would be due to the lost of storage capacity.

> "Activities that may directly or indirectly affect muskeg could nave a profound influence on the quality and quantity of streamflow...How the surface water system will respond to various types of muskeg disturbance is the most complex factor to be considered. With the available chemical data, only the particular case where the muskeg is removed and replaced by mineral soil is amenable for analysis. Once an area has been reclaimed and vegetation has been re-established, we visualize that its

hydrologic response will be similar to watersheds without muskeg. This assumption is reasonable as a first approximation because the presence or absence of surface water storage in muskeg will be one of the most important controls on streamflow. Discharge will be greater during spring runoff period and less during summer because the storage capabilities of muskeg have been eliminated from the system. Between storm events in summer, ion concentrations in the stream water will increase to levels in groundwater because drainage from muskeg, low in dissolved mineral matter, will no longer act to dilute the more mineralized groundwater" (Schwartz and Milne-Howe 1982, p. 302).

If a muskeg area is disturbed during construction of a road or other mine facility, one could assume that the water storage and filtering capacity of that portion of muskeg would be reduced and some decomposition of uprooted vegetation would occur. Therefore, there would be an increase in suspended solids, organic carbon, and nutrients, and a reduction in dissolved oxygen. Due to the lack of actual monitoring data or documented literature information on this specific subject, it is not possible to determine the magnitude of these changes.

If a muskeg area is completely removed (i.e., scraped up and hauled away with the overburden, or covered over by waste rock), then the storage capacity and effects of muskeg on water quality would be lost in that portion of the drainage basin. Surface runoff would not be retained and would carry a higher sediment load, and surface water quality during periods of low flow would reflect groundwater characteristics, i.e., more mineralized. For the Beaver Creek and White/Hill Creek drainage basins, the disturbed muskeg areas will be located behind the sedimentation ponds so suspended solids will be settled out and the decanted water will provide a substantial portion of the base flow during the low flows periods to dilute the groundwater contribution.

B. ACID-PRODUCING POTENTIAL OF WASTE ROCK

Acid-leaching information was obtained from the review of 39 references, including those provided by U.S. Borax as of July 31, 1985.

- The production of acid mine waters arises from the oxidation of metallic sulfide minerals. Initially, when the freshly exposed rock surfaces undergo weathering, iron is dissolved, releasing ferric ions, which in turn oxidize metal sulfides (Bruynesteyn and Hackl 1982). This oxidation can occur either chemically or biologically, but iron-oxidizing bacteria such as *Thiobacillus ferrooxidans* and other related species are always present in acid mine waters, suggesting that the biological mechanism is predominant. The sulfuric acid that is formed reduces the pH of the interstitial water, providing an acidic environment for these iron oxidizing bacteria (Silverman 1967; Kleinman et al. 1981). Bacterial oxidation of ferrous iron by bacteria of the Ferrobacillus-Thiobacillus group is rapid at pHs between 2.5 and 4.2 (Ehrlich and Fox 1967). Some of the species can adapt to pHs as low as 1.5, but no growth is supported above pH 6.0 (Vishniac

1974). These bacteria obtain energy for growth from the oxidation of sulfides, particularly pyrite (FeS_2) but also from chalcopyrite ($CuFeS_2$), molybdenite (MoS_2), pyrrhotite (Fe_7S_8) and sphalerite (ZnS), creating a more acidic environment (Razzell and Trussell 1962). All five of these sulfides are found in Quartz Hill ore (see Appendix A, Table II-1). Copper, zinc, and other metals become more soluble at low pH values and are leached from the rock surfaces.

- Tolerance studies revealed that _T. ferrooxidans_ is strongly inhibited by the oxidation product of molybdate ion, and molybdenum (as molybdate) at concentrations above 5 mg/l is actually lethal to this strain (Tuovinen et al. 1971). However, numerous microbiological leaching studies have documented accelerated oxidation of molybdenite by iron-oxidizing bacteria (Bryner and Anderson 1957; Bryner and Jameson 1958; Brierley and Murr 1973). There are two possible explanations for this apparent discrepancy. First, the tolerance studies were performed as batch experiments where the molybdate ions were allowed to concentrate within the flask, while the leaching studies were continuous-flow experiments where percolation solutions are flushed through oxidizing columns carrying away end-products such as molybdate ions. Therefore, the molybdate ion was not allowed to reach a concentration that would inhibit _T. ferrooxidans_ activity. Or, in the leaching experiments there were other strains of iron-oxidizing bacteria present which are not inhibited by molybdate ions such as _T. thiooxidans_ or _Sulfolobus sp._ (Ehrlich 1981). In either case, the presence of molybdenum in the rock body will not necessarily prevent the production of acid drainage in the waste rock disposal areas.

- U.S. Borax proposes that since the Quartz Hill ore body has approximately just 1 percent pyrite, the possibility of acid-leaching occurring is very small. The reported calculated or theoretical content of pyrite in the ore body ranges from 0.50 percent to 1.89 percent (U.S. Borax 1984g). The sulfur content (which represents all sulfides in the ore body and not just pyrite) is reported as 0.63 percent in the project description, but how representative this sample is of the entire ore body was not determined. The percent sulfur content in the ore samples analyzed by U.S. Borax in 1979 that exhibited acid-producing potential ranged from 0.39 percent to 0.82 percent (U.S. Borax 1980).

- An ongoing study in Minnesota with waste rock stockpiles of Duluth gabbro-containing copper, nickel, zinc, and iron sulfides with percent sulfur ranging from 0.63 percent to 1.41 percent revealed acid-production occurring around 0.79 percent sulfur and above (Eger and Lapakko 1980; Eger et al. 1981; Eger and Lapakko 1981). The leachate had alkalinity ranging from 15-25 mg/l as $CaCO_3$. Quartz Hill surface waters have an average alkalinity of about 10 mg/l as $CaCO_3$, which means these waters are very poorly buffered. They have less buffering capacity than the leachate monitored in the Minnesota study; so one could assume the Quartz Hill rock would have less acid-consumption.

- A standard test has been developed by B.C. Research of Canada to determine whether any of the rock types that will be exposed or disturbed in the course of operations have an acid-producing potential (Duncan and Waldon 1972). This test should be carried out on a number of split drill core or of randomly selected grab samples that are truly representative of the rock types being examined. There are two parts to this test: (1) the initial test to determine if the sample has acid-producing potential based solely on the intrinsic chemistry of the mineralization, and (2) the confirmation test to determine if the sulfide oxidizing bacteria can generate enough sulfuric acid from the sulfides present in the sample to satisfy its acid demand.

  Initial Test

  1. The acid-generating ability is determined based on assay of sulfur values.

  2. The acid-consuming ability due to the presence of carbonates or other buffering compounds in the rock type is determined from an acid titration procedure.

  3. Acid-producing potential = acid-generating - acid-consuming. If the acid-consumption is less than the acid-generation, the possibility of acid mine water production exists and the confirmation test should be conducted.

  Confirmation Test

  A rock sample is inoculated with *T. ferrooxidans* and a nutrient medium at a pH of 2.5 and then monitored to see if the bacteria can generate enough sulfuric acid to maintain growth over a 5-7 day period.

- U.S. Borax carried out the initial test on 13 ore samples in 1979 in their own California labs and found 4 to have acid-producing potential (U.S. Borax 1980). The location of the these samples and how representative they are of the Quartz Hill ore body to be mined were not determined, and the confirmation tests were not performed on the 4 acid-producing samples.

- U.S. Borax carried out another series of initial tests on four Quartz Hill adit rock samples, a composite of Bear Meadow adit samples, and two "waste rock" samples in 1983 (U.S. Borax 1984h). Only the Bear Meadow composite sample (specifically, five out of the six rock types which made up the composite) exhibited acid-producing potential. In 1984, confirmatory tests with bacteria were performed on these five rock types and the composite with negative results. Even the rock type with the highest theoretical net acid production did not support *T. ferrooxidans* activity (U.S. Borax 1985a). However, because these rock samples are from the adits, they are considered ore samples, and even

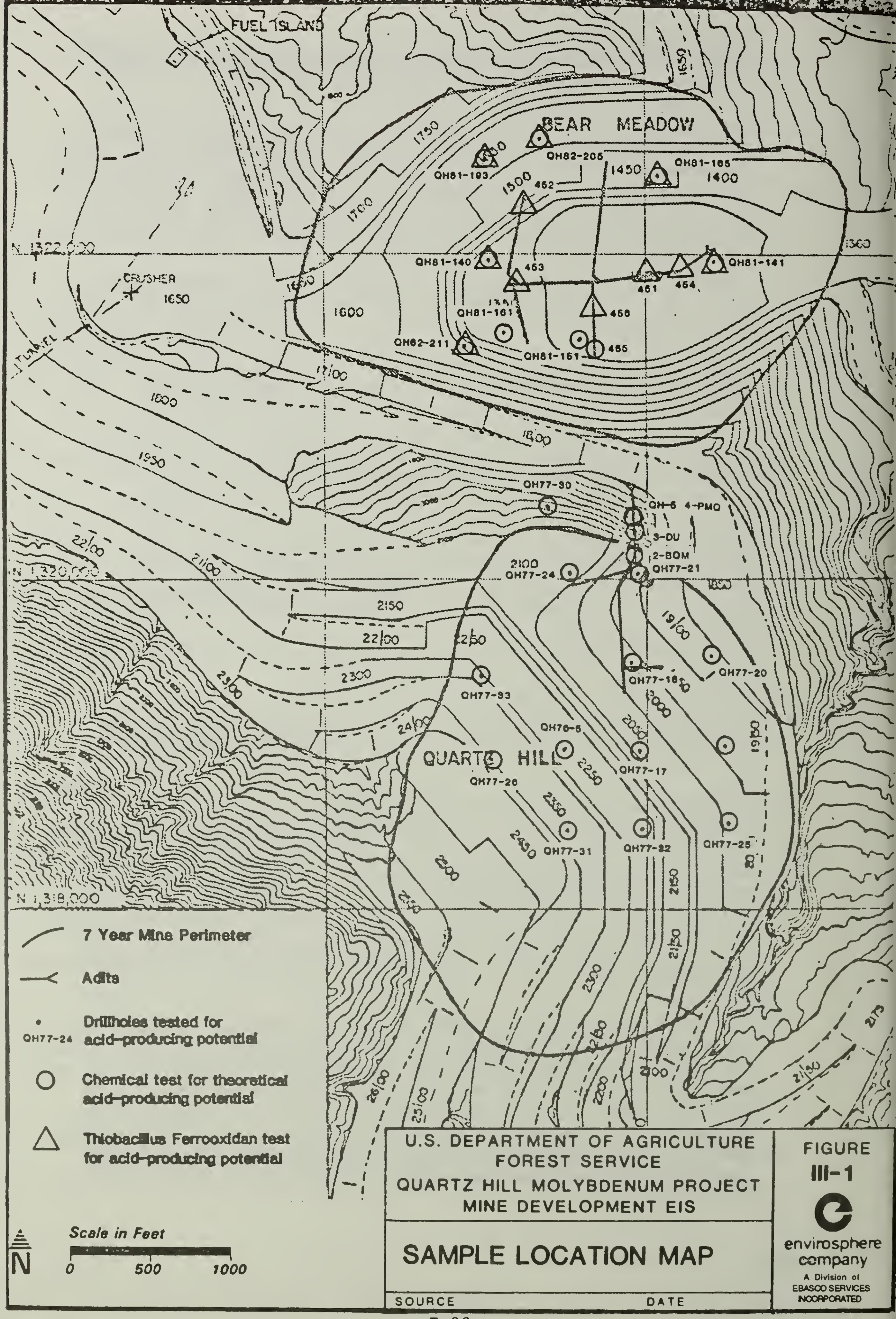
though they have very similar mineral characteristics as waste rock, there was some doubt whether they represented the acid-producing characteristics of the projected waste.

- The "waste rock" samples analyzed in 1983 were actually glacial till obtained from along the road cuts. According to the project description in Appendix A, glacial till makes up only a fraction of the waste rock to be disposed (95 mcf glacial till in 900 million tons of waste rock). In light of this, the "waste rock" samples analyzed by U.S. Borax could not be considered truly representative.

- In response to the suggestion in the DEIS and several agency requests, U.S. Borax performed both the initial chemical analysis and confirmation test with bacterium on representative samples of waste rock from the area to be mined. The most recent tests used samples taken from 5-ft sections of drill core in what will be waste rock from the Bear Meadow sector of the first seven years of operation. The sample locations are shown on Figure III-1. Two reasons for the use of Bear Meadow samples are the following: (1) about 60 percent of the waste rock produced in the first seven years will come from the Bear Meadow pit and (2) very little evidence has been found for theoretical net acid producing potential rock in the Quartz Hill sector of the ore body. Special effort was made in the selection of the waste rock samples to be sure that they are representative of the waste rock to be mined during the early years of development. The selection procedure was based on the recommended EPA methods (EPA 1982). Of 116 samples of waste rock, 30 were selected for testing by using a random number generator. By this procedure, each 5-ft section of drill core had an equal chance to be selected for testing.

  The initial or theoretical net acid potentials found for the samples covered a wide range from 64.7 pounds H_2SO_4 produced per ton of rock to 154.8 pounds H_2SO_4 consumed per ton of rock. The testing with T. ferrooxidans by a modified B.C. Research procedure was carried out by Ultra Systems, Inc., Irvine, California, who have had testing experience with coal and eastern oil shale. A set of 11 samples was selected from the 30 samples of waste rock drill core described above. This set was chosen to provide a range of theoretical net acid producing potential above and below the highest potential tested before. Since the highest value tested before had seemed borderline, it was thought that there might be a "cutoff" value, above which actual acid production would occur.

  The initial findings are based on chemical analyses of rock samples where total sulfur is equated to the level of acid production and the acid consumption figures are determined by titration. The real world situation contains many variables that alter the simple chemical relationships, especially on the acid production side of the equation. The results of the biological confirmatory testing with T. ferrooxidans indicate that acid drainage should not be produced from the first seven years production of waste rock (U.S. Borax 1985b).


FUEL ISLAND
BEAR MEADOW
CRUSHER
TUNNEL
N 1,322,000
N 1,320,000
N 1,318,000
QUARTZ HILL
QH81-193
QH82-205
QH81-165
462
QH81-140
463
461
464
QH81-141
QH81-161
456
QH82-211
QH81-151
455
QH77-30
QH-5 4-PMO
3-DU
2-BOM
QH77-21
QH77-24
QH77-16
QH77-20
QH77-33
QH76-5
QH77-17
QH77-26
QH77-31
QH77-32
QH77-25
7 Year Mine Perimeter
Adits
Drillholes tested for acid-producing potential
QH77-24
Chemical test for theoretical acid-producing potential
Thiobacillus Ferrooxidan test for acid-producing potential
Scale in Feet
0
500
1000
N
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
SAMPLE LOCATION MAP
SOURCE
DATE
FIGURE
III-1
envirosphere company
A Division of EBASCO SERVICES INCORPORATED

Although the entire waste rock composition and acid producing potential have not yet been explored, the initial seven-year waste rock tests have indicated no particular acid drainage problems. Evaluation of waste rock would be an ongoing process as the mine is developed including further chemical analyses of core drill samples (Appendix A, Section II.A.3).

C. PRELIMINARY ESTIMATION - BLASTING COMPOUND RESIDUE

Blasting compound residue and spillage may be transported in surface runoff and be discharged into waterways. Typical nitro-carbon-nitrate explosives, NH_4NO_3 based with detonators and "fuel oil" binders (ANFO), will be used in the mine pit area. Usage rates are estimated at 46,000 lb/day NH_4NO_3 1/ and 460 gals/day fuel oil. A misfire/dud rate of one blast hole/month 2/ is assumed as an upper limit.

Calculation of discharge residue:

Daily ore/waste rock removal: 10 yard-depth x 20 yard-height x 30-yard length $\simeq$ 60,000 yard^3 $\simeq$ 80,000 tons/day

Assume 3 shots per day in an arrangement of 15 holes per shot are required to extract to extract 80,000 tons/day

Estimate a hole size with a 13 in. diameter, 10 yards deep into which
a depth of 3 feet of blasting compound is packed.

Volume of compound packed = π (13/in./12 in. per foot)^2 x 3 feet = 11.1 ft^3 compound/hole

Mass of NH_4NO_3 in one hole assuming density of 65 lb/ft^3 = 11.1 ft^3/hole x 65 lbs/ft^3 = 720 lb compound/hole

At an explosive dud rate of 1 hole/month, 720 lb NH_4NO_3 per month or 24 lb per day along with 2.4 gals/day of fuel oil remains in the removed material. The successful detonation of ANFO is assumed to produce only the combustion products of CO_2, H_2O, and N_2 and no NH_3, NO_3, or hydrocarbons. 3/

Spillage of NH_4NO_3 and fuel during charging of holes:

Assume spillage of 0.05 percent

NH_4NO_3 spillage: 46,000 lbs/day x 0.0005 = 23 lbs/day NH_4NO_3

Fuel oil spillage: 460 gals/day x 0.0005 = 0.23 gals/day fuel oil

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1/ Stine 1983.
2/ Sheflott 1983b.
3/ Tillman 1983.

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Total NH_4NO_3 and fuel oil entering rock/soil material:

24 lb NH_4NO_3/day misfire
23 lb NH_4NO_3/day spillage

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47 lb NH_4NO_3/day

0.24 gal fuel oil/day misfire
0.23 gal fuel oil/day spillage

0.47 gal fuel oil/day

As a worst case, all residual NH_4NO_3 and fuel oil are assumed to be carried in runoff water into waterways. A flow of 23.3 MGD is assumed.

NH_4NO_3 concentration:

$$(47 \text{ lbs/day } NH_4NO_3)/(8.33 \text{ lbs/gal} \times 23.3 \times 10^6 \text{ gals/day}) = 0.26 \text{ ppm } NH_4NO_3$$

Fuel oil concentration:

$$(0.47 \text{ gals/day fuel oil} \times 6.7 \text{ lbs/gal}) / (23.3 \times 10^6 \text{ gals/day} \times 8.33 \text{ lbs/gal}) = 0.02 \text{ ppm fuel oil}$$

The oil and grease concentration of 12 mg/l and the total Kjeldahl nitrogen concentration of 2.6 mg/l in the mine drainage effluent greatly exceed the worst case estimate of runoff concentrations of explosive residue. Therefore, the impact from wasted explosive residues on water quality is small compared to other sources.

D. TREATMENT WITH WATER QUALITY CONTROL FACILITIES

As described in Appendix A, Section II.A.7, runoff and discharges from construction and operation activities will be collected and routed through water quality control facilities. Small dams will be constructed on upper Beaver Creek and White Creek as interim structures, and larger dams on lower Beaver Creek, Hill Creek, and Tunnel Creek. Estimated runoff and streamflows to facilities during 10-yr, 24-hr and 100-yr, 24-hr storm events are presented in Table III-1. The facilities will be designed, constructed, and maintained to contain the maximum volume of wastewater generated by the facility during normal operating conditions without an increase in volume from precipitation and the maximum volume of wastewater resulting from a 10-yr, 24-hr precipitation event, as stipulated by EPA (40 CFR Part 440.131[c]).

The facilities will initially function as sedimentation ponds, primarily treating the runoff water through settling of suspended solids. Removal of soluble constituents will be minimal and will not change appreciably during storm events.

TABLE III-1

ESTIMATED RUNOFF AND STREAMFLOW TO FACILITIES DURING STORM EVENTS

Sedimentation Pond	Drainage Area (mi^2)	Overall 1/ Runoff Coefficient	10-yr, 24-hr 2/ Precipitation		100-yr, 24-hr 3/ Precipitation	
			Runoff Volume (ft^3)	Streamflow (cfs)	Runoff Volume (ft^3)	Streamflow (cfs)
Upper Beaver Creek (yr 6)	2.21	0.84	4.14×10^7	479	5.69×10^7	658
Lower Beaver Creek (>yr 6)	2.47	0.86	5.51×10^7	662	7.68×10^7	889
White Creek (<yr 15)	2.96	0.89	5.88×10^7	680	8.29×10^7	959
Hill Creek (>yr 15)	12.7	0.85	24.4×10^7	2,960	35.8×10^7	4,140

1/ Overall runoff coefficient estimated by area-weighted values for the surfaces comprising the catchment.

2/ Estimates based on 0.8 ft^3/ft^2 precipitation in a 10-yr, 24-hr precipitation event.

3/ Based on data from U.S. Borax (1983a).

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The adequacy of the sedimentation ponds in removing suspended solids may be estimated from a theoretical analysis of particle settling. Sedimentation increases as more time is allowed for settling, and larger particles generally settle faster than smaller particles. The fraction of the suspended sediment load in Quartz Hill waterways that is removed increases as the hydraulic retention time (ratio of reservoir capacity to influent or effluent flow rate) increases and decreases as the proportion of small particles in the total sediment load increases. Estimates of hydraulic retention times assuming a filled reservoir and complete mixing are presented in Table III-2. Based on hydraulic retention times and reservoir geometry, the diameter of the "critical particle" is calculated. In theory, all particles larger than the critical particle will settle and those smaller will not settle completely or at all. Conditions of average annual streamflow and that during 10-yr, 24-hr and 100-yr, 24-hr events are chosen to estimate effluent water quality for normal operation, maximum flow conditions, and overtopping, respectively.

Effluent suspended solids concentrations for different flows depend on the suspended solids size distribution and on the size of the critical particle. Estimates of the critical particle are about 0.005 mm during normal flow, which increases to 0.020 mm for the 10-yr, 24-hr event and 0.025 mm for the 100-yr, 24-hr event. Particles less than 0.020 mm in diameter and greater than 0.005 mm, which would be contained during average streamflow, would be transported during the 10-yr, 24-hr precipitation event. Little data are available for suspended solids size distributions in the Quartz Hill waterways. Data from the Keta and Blossom rivers indicate that increased total suspended solids (TSS) loadings associated with larger streamflows are primarily due to increases in large-sized particles. The TSS load of the Keta River at 984 cfs was 28 mg/l, comprised of 4.5 mg/l sand in the 4.00 mm to 0.062 mm range and 23.5 mg/l silt/clay at less than 0.062 mm. The 79 mg/l TSS load of the Blossom River at 3,900 cfs contained 64 mg/l sand and 15 mg/l silt-clay (VTN 1984). Although particles greater than 0.005 mm and less than 0.020 mm will be transported during storm events, the TSS concentration in this size range may not change appreciably. Therefore, despite the increase in size of the critical particle, the particle size distribution of suspended sediments during storm events is such that most of the increase in TSS can be controlled by the reservoir. Furthermore, reservoirs will normally be operated at an almost empty state. This is significant in that a retention time larger than listed is available as the reservoir fills during storm events, enhancing settling of suspended solids.

The frequency of overtopping of the sediment dams can be estimated from Weiball's estimation of return period (Weiball 1939, in Linsley 1975).

$$Tr = (n + 1)/m$$

- Tr = return period, average number of years an event will be exceeded or equaled.
- n = number of years of record
- m = magnitude rank of event, largest = 1

TABLE III-2

RETENTION TIMES AND SEDIMENT CAPTURE OF
SUSPENDED SOLIDS BY FACILITIES DURING STORM EVENTS

Sedimentation Pond	Design 1/ Capacity (ft^3)	Hydraulic 2/ Retention Time (hr)			Particle Size 3/ Capture (mm)		
		Average Flow	10-yr 24-hr Event	100-yr 24-hr Event	Average Flow	10-yr 24-hr	100-yr 24-hr
Upper Beaver Creek	5.2×10^7	600	30	22	.004	.017	.020
Lower Beaver Creek	6.5×10^7	620	28	20	.005	.022	.025
White Creek	1.0×10^8	860	42	29	.004	.018	.021
Hill Creek	3.0×10^8	610	28	20	.007	.031	.036

1/ U.S. Borax, 1983e.

2/ Assumes complete mixing; volumetric inflow from Table III-2; no provision is made for capacity lost to sediment volume.

3/ Equation: $V_s = \frac{g\ (\rho_s - \rho)}{18} \frac{d^2}{\mu}$

V_s = settling velocity
g = gravitational acceleration
ρ_s = particle density
μ = water viscosity (8°C)
d = particle diameter
ρ = water density

Particle capture indicates the smallest particle (the critical particle) which theoretically will settle completely. The percent removal of smaller particles will decrease as the particle size decreases (Metcalf and Eddy 1979).

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The rank of the 10-yr event in 50 years is five, so that statistically four overtopping events will exceed the 10-yr event. During the project life, the actual overtopping frequency will likely differ due to the uncertainty of the 10-yr event estimate and statistical variation. Calculations of the critical particle size during the 100-yr, 24-hr event indicate a size comparable to that based on the 10-yr, 24-hr event, so water quality impacts during overtopping may be comparable to impacts during the 10-yr, 24-hr event.

If natural sedimentation is found to be inadequate or modification of other water quality parameters is required, other treatment alternatives or supplements that might be considered include ion exchange, hydroxide precipitation, flocculation, and smaller dams in series.

Ion exchange resins remove heavy metals and certain anions very effectively. However, the streamflow of the various project creeks far exceed the design capacity of conventional ion exchange systems. Also, the cost of resin alone would be prohibitive, exceeding $1 million per year (based on 2 gals/min/ft^3 loading, 24 cfs, $150/$ft^3$ resin; EPA 1981).

By adding basic or alkaline substances such as lime to the water, metals may be precipitated from solution as hydroxides. However, the estimated metal concentrations are too low to be effectively precipitated and the addition of alkaline substances may produce unnaturally high pH values.

Flocculation involves the addition of chemicals that help gather and settle suspended particles. The cost of flocculent alone would exceed $300,000 per year (based on a dose of 0.02 lbm/1000 gal; and $2.50/lbm polyelectrolyte; EPA 1981) for continuous application to one pond. Although intermittent use would be less costly, in practice, flocculent addition may not improve sedimentation and introduces another chemical into the water.

Sedimentation reservoirs provide quiescent water in which particles can settle. The larger the reservoir, the more efficient is suspended sediment removal due to increased time for settling. Therefore, one large dam removes suspended sediment better than a series of small dams. Of the various treatment alternatives considered, large sedimentation reservoirs are the most effective and reliable in improving water quality without being prohibitively costly.

E. TURBIDITY AND SEDIMENTATION

As shown in Section II.B, Table II-1, Alaska Receiving Water Quality Standards include limits on turbidity. Turbidity is an indirect measure of liquid clarity. Measurements are made by quantifying the amount of light which the liquid sample reflects. The measurements are expressed as nephelometric turbidity units (NTU) defined according to prepared calibration standards. The size, shape, color, and quantity of particles present in the liquid all determine to some extent the amount of reflected light and thus the turbidity measurement.

Turbidity is often related to total suspended solids, but not in all cases. For example, many coloring agents that contribute to turbidity will pass through filters used to quantify suspended solids. Conversely, a significant concentration of dark suspended solids, which absorb instead of reflect light, may be measured as negligible turbidity.

A statistically significant correlation between total suspended solids and turbidity measurements may be determined for a particular waterway. However, a correlation for one waterway cannot be applied to other waterways (Duchrow and Everhart 1971). Little suspended solids-turbidity data are available for Quartz Hill waterways, especially for turbidity values greater than 10 NTU or TSS greater than 10 mg/l. Statistical analyses of available suspended solids and turbidity data (VTN 1984) for several streams revealed no correlations. More field data will not appreciably aid in predicting turbidity due to the complexity and variability of the sources of turbidity and removal mechanisms. Therefore, compliance with ADEC regulations for turbidity cannot be correlated with estimated suspended solids concentrations in the mass balances, but instead must be established in an ongoing monitoring program as established in state permits.

ADEC Sedimentation Standards are defined according to the deviation in the amount of 0.1 mm - 4 mm particles in streambeds. Predictions of instream sedimentation are difficult due to the complexity of transport and deposition processes. Monitoring and possible remedial action for sedimentation must also be covered in state permits.

F. COMPARISON OF DISSOLVED, TOTAL, AND TOTAL RECOVERABLE METAL CONCENTRATIONS

The trace metal concentrations for the influent characteristics from disturbed areas presented in Table 4-3 are the dissolved portion only. These concentrations represent those metals which pass through a 0.45 micron membrane filter. The proposed Alaska Receiving Water Quality Standards for metals are based on EPA water quality criteria. These criteria are based on the total recoverable assay technique, which measures the metals in an unfiltered sample following treatment with hot dilute mineral acid. The NSPS effluent limitations are based on total metal concentrations, which are determined from an unfiltered sample following vigorous digestion. Obviously, the total and total recoverable assay techniques measure both the dissolved metals and those metals associated with the suspended solids. Therefore, these concentrations are usually higher than those obtained from the dissolved analysis. Since dissolved metal concentrations for disturbed areas represent a different measurement than total recoverable or total metals, it is not theoretically valid to conclude that there will be compliance with the NSPS effluent limitations or ADEC standards. However, the following evaluation demonstrates how the three metal assay methodologies were found to be comparable in this analysis for the major metals of concern in the mass balances.

Total concentration of metals in the outfall discharge could conservatively be defined as the dissolved metals concentration plus the extractable concentration from the suspended solids.

[Total] mg/l = [Dissolved] mg/l + [Extractable] mg/l

where [Extractable] mg/l = [SS] mg/l x [Extractable] mg/mg

In the chemical oceanography analysis for metals concentration from tailings discharges, Burrell determined that on the average 44 percent of the metals in the tailings solid are extractable (See Table F-6). For this conservative analysis, assume that all of the metals associated with the suspended solids in runoff from disturbed areas are extractable. Therefore, the total concentration for each metal from the ore characterization in Appendix A, Table II-1 or tailings characterization in Appendix A, Table II-7 will be used as the extractable portion.

	Ore Characterization		Tailings Characterization Solid Phase		Extractable Portion a/
	(Weight Percent)	(10^{-3} mg/mg)	(ppm)	(10^{-3} mg/mg)	(10^{-3} mg/mg)
Arsenic	--	--	10.9	0.0109	0.0109
Cadmium	--	--	2.4	0.0024	0.0024
Copper	0.009	0.09	69.0	0.0690	0.09
Iron	1.690	16.90	--	--	16.90
Lead	0.006	0.06	47.0	0.0470	0.06
Manganese	--	--	462.0	0.4620	0.462
Molybdenum	0.217	2.17	120.0	0.1200	2.17
Zinc	0.004	0.04	46.0	0.0460	0.046

	Extractable Portion (10^{-3} mg/mg)	x	Suspended Solids b/ (mg/l)	=	Extractable Conc. (10^{-3} mg/l)
Arsenic	0.0109		20.0		0.218
Cadmium	0.0024		20.0		0.048
Copper	0.09		20.0		1.80
Iron	16.90		20.0		338.0
Lead	0.06		20.0		1.20
Manganese	0.462		20.0		9.24
Molybdenum	2.17		20.0		43.40
Zinc	0.046		20.0		0.92

a/ Use the higher of the two metal concentrations as the extractable portion.

b/ U.S. Borax has committed to meeting the NPDES effluent limitation of 20 mg/l as the daily average suspended solids concentration.

For the dissolved concentration values, the highest metal concentrations which occur in the discharge from outfall 001 in Scenario No. 2 - Beaver Creek at year 55 will be used (see Table III-5).

	Extractable Concentration (mg/l)	+	Dissolved Concentration (mg/l)	=	Total Concentration c/ (mg/l)
Arsenic	0.000218		0.013		0.013
Cadmium	0.000048		0.004		0.004
Copper	0.00180		0.009		0.011
Iron	0.3380		0.644		0.982
Lead	0.00120		0.019		0.020
Manganese	0.00924		0.442		0.451
Molybdenum	0.04340		0.992		1.035
Zinc	0.00092		0.026		0.035

c/ Values are rounded to 3 decimal places to correspond with detection limits of existing water quality measurements.

Even though the most conservative metal concentrations for suspended solids were used to estimate extractable metal concentrations, the resulting estimated total concentrations for most of the metals are not significantly higher than the dissolved concentrations that were used in the RDEIS to evaluate compliance with ADEC Receiving Water Quality Standards. Copper, iron, manganese, and molybdenum concentrations were significantly increased by adding the extractable portion. Below is a comparison of these conservative estimates of total metal concentrations to existing Beaver Creek concentrations and proposed ADEC Receiving Water Quality Standards.

	Total Concentration (mg/l)	Beaver Creek Existing (mg/l)	Proposed ADEC Standards (mg/l)		
			Acute	Chronic	DW
Arsenic	0.013	0.005	0.360	0.190	0.05
Cadmium	0.004	0.002	0.0039	0.0011	0.010
Copper	0.011	0.003	0.018	0.012	1.0
Iron	0.982	0.145	---	1.000	0.3
Lead	0.020	0.010	0.082	0.0032	0.05
Manganese	0.451	0.009	---	---	0.05
Molybdenum	1.035	0.020	---	---	---
Zinc	0.035	0.009	0.12	0.11	5.0

Even with the addition of the extractable portion, the total value for iron is still less than the proposed standard. The dissolved value for manganese exceeded the standard in all of the scenarios evaluated in the RDEIS, so adding on the extractable portion would just extend the length of the required mixing zones downstream of the outfalls. There is no standard for molybdenum; it was included in the DEIS analyses because of its association with the Quartz Hill ore body.

If the extractable portions were reduced to 44 percent of the characterization values, as in the chemical oceanography analyses in Appendix F, their contribution to the total concentration would be even more insignificant when compared to the dissolved values. The water quality mass balances in Section I of Appendix E could be revised using total values, but the differences would be insignificant both with respect to standards and in the absolute sense.

G. CHARACTERIZATION OF INFLUENT TO WATER QUALITY CONTROL FACILITIES FROM DISTURBED AREAS

Table III-3 presents a proposed characterization of influent to the water quality control facilities from the disturbed areas. This influent characterization was used to represent mine pit dewatering and runoff from three disturbed areas: waste rock and overburden disposal areas, mine service and personnel housing areas, and the mine area access and haulage roads. Because the sites for the mine service and personnel housing areas, as well as the roads, will be constructed from crushed waste rock, runoff from these surfaces should be similar to that from the waste rock disposal areas. An appropriate characterization of this runoff was not found in the literature, so instead, use of the mine adit drainage data was proposed. It is assumed that this characterization would take into account the most adverse soil, slope, and climatic conditions. The range of water quality values obtained from short-term field experiments with muskeg, dike material, and ore were found to correspond with the adit drainage values. Therefore, the disturbed areas characterization was developed from the Bear Meadow and Quartz Hill mine adit discharges monitored from July 1981 to March 1985 and the following assumptions.

1. For a conservative scenario, it was agreed that the maximum values for water quality parameters measured in the portal drainage from the two exploration mine adits should be used. Therefore, Parameters 2, 5 through 13, and 16 through 23 for the disturbed area characterization reflect the highest measured concentrations from the mine adit drainage presented in the center column, except where the maximum value is questionable or does not correspond with other project information.

2. Because U.S. Borax has committed to compliance with the federal suspended solids standard, in the mass balances the disturbed area characterization value was back calculated to provide a concentration of 20 mg/l at the outfall discharge. Without the specific design parameters and operating procedures for the water quality control facilities and a representative particle size

TABLE III-3

CHARACTERIZATION OF INFLUENT TO WATER QUALITY CONTROL FACILITIES FROM DISTURBED AREAS

Parameters (mg/l or as noted)		Mine Adit Drainage (July 1981-March 1985)1/	Disturbed Area Characterization
1	pH, units	5.8-10.2	7.0
2	Total dissolved solids	120-500	500
3	Hardness (as $CaCO_3$)	120-310	200
4	Alkalinity (as $CaCO_3$)	86-330	150
5	Oil and grease	<0.10-44 2/	12
6	Total organic carbon	9.6-17	17
7	NH_3 and org nitrogen (as N)	<0.10-2.6	2.6
8	Nitrate nitrogen (as N)	0.18-4.0	4.0
9	Total phosphorus (as P)	0.04-0.13	0.13
10	Silica (as SiO_2)	13-18	18
11	Sulfate (as SO_4)	23-240	240
12	Chloride	4-7	7
13	Calcium	39-100	100
14	Suspended solids	<1-4,000 3/	-- 6/
15	Dissolved oxygen	-	7.0
16	Arsenic 4/	<0.005-0.014	0.014
17	Cadmium	<0.001-0.004	0.004
18	Copper	<0.005-0.094 5/	0.010
19	Iron	<0.005-0.700	0.700
20	Lead	<0.005-0.020	0.020
21	Manganese	0.016-0.490	0.490
22	Molybdenum	0.230-1.100	1.100
23	Zinc	<0.002-0.028	0.028

1/ See Appendix A, Table II-2.
2/ Next highest reading was 12 mg/l.
3/ Next highest reading was 520 mg/l.
4/ All trace metals are dissolved portion only.
5/ Next highest reading was 0.010 mg/l.
6/ Suspended solids concentration was back-calculated for each mass balance scenario so that the discharge would be 20 mg/l.

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distribution, it is impossible to model or quantify the settling of suspended sediments in the ponds under various scenarios and flow conditions. Refer to Appendix A, Section II.A.7 for the detailed discussion on compliance and assumptions about the water quality control facilities.

3. The results of the biological confirmatory testing with T. ferrooxidans performed to date indicate that acid drainage should not be produced from the first seven years' production of waste rock (Appendix E, Section III.B) and probably will not be a problem throughout the life of the mine operation due to the inherent acid-consuming capacity of the deposit. If acid-producing potential is detected, the mine waste rock disposal plan proposed by U.S. Borax (Appendix A, Section II.A.3) should adequately prevent any extensive chemical or microbiological leaching of the waste rock. Consequently, there should be no noticeable decreases in pH or increases in trace metal concentrations in the runoff from the waste rock disposal areas compared to what has been measured in the mine adit drainage.

4. For Parameter 1, the average pH from the mine adit drainages was chosen for the disturbed area characterization because the extreme values in no way could be considered representative of runoff from a variety of disturbed areas.

5. According to the database, total hardness values for the Quartz Hill adit range from 120 to 138 mg/l as $CaCO_3$ and values for the Bear Meadow adit range from 254 to 310 mg/l. The higher hardness values from the Bear Meadow adit reflect the exposure of groundwater to carbonate rock formations. Marble type formations have been noted along Stephan's fault, which runs through the mine pit area, but the extent of these carbonate rock formations throughout the area are not known. The geological data characterize the area as primarily sulfide mineralizations. Therefore, for Parameter 3 a more reasonable total hardness value of 200 mg/l was used to correspond with the predominant rock formations.

   Similarly, for Parameter 4, the total alkalinity value was adjusted to 150 mg/l to correspond with total hardness. The Quartz Hill adit alkalinity values range from 86 to 93 mg/l as $CaCO_3$, while the Bear Meadow values range from 150 to 330 mg/l.

6. Parameter 15, dissolved oxygen, was not measured for the mine adit drainage; therefore, a reasonable value was calculated from baseline groundwater and surface water concentrations to reflect input from mine pit dewatering and surface runoff.

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H. RESULTING DOWNSTREAM WATER QUALITY SCENARIOS AND MIXING ZONES - ASSUMPTIONS AND MASS BALANCES

U.S. Borax has committed to designing water quality control facilities so that the water, which is to be decanted from the facilities usually on a continuous basis into the creeks below the dams, will comply with the NPDES effluent limitations as established by Region 10 of EPA and with the Alaska Receiving Water Quality Standards (see Appendix E, Table II-1) as administered by the Alaska Department of Environmental Conservation. The decanted water must comply with the NPDES effluent limitations at the point of discharge. The ADEC, according to 18 AAC 70.032, allows for some dilution of the decanted water by the creek. Therefore, compliance with the Alaska Receiving Water Quality Standards occurs at the boundaries of the ADEC approved mixing zones.

In order to estimate whether the water quality control facilities as presently envisioned will provide adequate treatment, mass balances of water quality parameters for influents to the facilities and discharges to receiving streams were performed. To simplify these mass balances, the influents were grouped into just two characterizations. Mine pit drainage and runoff from waste rock and overburden disposal areas, mine service and personnel housing areas, and the mine area access and haulage roads are represented by the characterization of influent from disturbed areas developed in the previous Section E, Table III-1. Runoff from areas undisturbed by mining activities and snowmelt are represented by the appropriate existing surface water quality characterization in Table 3-5.

Compliance with NPDES effluent limitations was evaluated by mixing water with disturbed and undisturbed characterizations and comparing the resulting discharge to the effluent limitations for molybdenum mine drainage, New Source Performance Standards (NSPS) 40 CFR 440.104(a) (Section II.A). The contribution of each influent characterization to the water quality control facility was based on the corresponding percentages of disturbed and undisturbed areas in the drainage basin.

Compliance with ADEC regulations was evaluated by diluting the water quality control facility discharges with receiving water quality characteristics and comparing the resulting water quality values to the Alaska Receiving Water Quality Standards (Section II.B). The volume of dilution which is required to meet these standards established the extent of the mixing zone below each point of discharge for each parameter.

In order to project the discharge quality and mixing zone boundaries for each water quality control facility, mass balances were performed for four operational scenarios.

No. 1 - Beaver Creek at Year 6
(interim upper Beaver Creek water quality control facility and personnel housing area water quality control facility)

No. 2 - Beaver Creek at Year 55
(final lower Beaver Creek water quality control facility)

No. 3 - White/Hill Creek at Year 15
(interim White Creek water quality control facility)

No. 4 - Hill Creek at Year 55
(final Hill Creek water quality control facility)

Both interim and final water quality control facility scenarios were developed in order to compare the resulting downstream water quality at different stages in the mine operation. Each of these mass balances were performed for both average annual flow and the 7-day, 10-year low flow conditions. See Appendix D for the detailed assumptions used to calculate these flows.

For determining compliance with ADEC regulations as established in Section III.B and the extent of mixing zones these specific standards based on the following assumptions were used in the computer program:1/

Parameter	mg/l
Dissolved oxygen	>7.0
Total dissolved solids	<500.0
Alkalinity	>20.0
Nitrate	<10.0
Sulfate	<200.0
Chloride	<200.0
Arsenic	<0.19
Cadmium	<0.0039
Copper	<0.012
Iron	<1.0
Lead	<0.083
Manganese	<0.1
Zinc	<0.047
Suspended solids	<20.0

Because the molybdenum-bearing rock body and mining operations would not typically be sources of chromium, mercury, nickel, selenium, or silver, existing water quality characterizations for these metals and compliance with federal and state standards were not evaluated.

The acute or one-hour average standards were used for cadmium and lead instead of the lower chronic standards because the stricter standards are below the detection limit of the data obtained on adit discharges and existing water quality.

1/ Analyses were based on the proposed ADEC standards as of 1984. Tables and text have been updated to reflect standards current as of October 1987.

In the DEIS, the Class 1A (i) standard of 500 mg/l for total dissolved solids (TDS) was presented as the proposed Alaska Receiving Water Quality Standard. However, according to ADEC this is not the strictest standard and Class 1A(iii), which requires that "increases of TDS shall not exceed one-third of the concentration of the natural condition of the body of water" should be used instead. This stricter standard will be addressed in the impact assessments below and in Section 4.1.5 Water Quality.

The specific assumptions, projected water quality, estimated mixing zones, computer printouts of the parameter mass balances, and the pH calculations are presented below for each scenario.

I. COMPLIANCE WITH WATER QUALITY STANDARDS AND MIXING ZONES

Compliance with the New Source Performance Standards at the point of discharge from the water quality control facilities is evident from the comparison of parameter values and standards in Tables III-8 and III-9. Even without the dilution from undisturbed runoff that will occur in the ponds behind the dams, the disturbed area characterization complies with the federal pH and selected metals standards.

Compliance with the proposed Alaska Receiving Water Quality Standards was evaluated for each scenario at both average annual and 7-day, 10-year low flows. The outfall waters in all of the scenarios comply with all of state standards without requiring a mixing zone except for three parameters: manganese, sulfate, and total dissolved solids in the following specific cases.1/

- o In all cases, the standard for manganese is exceeded. In scenarios No. 1 and No. 2 for Beaver Creek, the manganese concentration is not diluted to an acceptable level before reaching the confluence with the Blossom River; therefore, the mixing zone would have to extend beyond the fisheries habitat below Lower Beaver Creek Falls. At the point of confluence, the estimated manganese concentration for scenario No. 1 would be approximately 0.13 mg/l which is one-third greater than the standard. The confluence concentration for scenario No. 2 is estimated to be 0.35 mg/l or three and a half times the standard. In scenario No. 3 for Hill Creek, the mixing zone would have to extend approximately 15,000 feet downstream of the interim outfall, this zone boundary would still be 1,000 feet above the Lower Falls. For scenario No. 4, the mixing zone would have to extend 4,000 feet downstream of the Hill Creek outfall, but would still be 2,000 feet above the Lower Hill Creek Falls.

1/ Analysis based upon modeling results using proposed 1984 acute criteria and upon understanding with ADEC at that time. Application of 1987 chronic criteria values suggests a mixing zone would also be required for lead and cadmium (i.e., that lead and cadmium chronic criteria could be exceeded in the outfall waters).

RESULTING WATER QUALITY CHARACTERISTICS OF SCENARIO NO. 1 - BEAVER CREEK AT YEAR 6

Resulting water quality characteristics for this scenario are provided in Table III-4.

Assumptions

1. Influent from disturbed areas into the interim water quality control facility in upper Beaver Creek, Outfall 001 and discharges from the personnel housing area, Outfall 002, will have the water quality characteristics as presented in Table III-1.

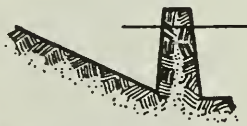
2. The flow in Beaver Creek just below the interim water quality control facility, Outfall 001, is essentially what was discharged.

3. Natural runoff from the portion of the drainage basin between the interim water quality control facility, Outfall 001, and Outfall 002 makes up the remainder of upper Beaver Creek flow and has Beaver Creek (BV-QC-1890) baseline water quality.

4. The discharge from the personnel housing area, Outfall 002, becomes mixed with the resulting upper Beaver Creek water at the point of discharge.

5. Natural runoff from the portions of the drainage basin between Outfall 002 and the Beaver Creek Falls and between the Falls and the mouth of Beaver Creek make up the remainder of lower Beaver Creek flow and have Beaver Creek (BV-QC-1890) baseline water quality.

6. Average annual flows and 7-day, 10-year low flows were obtained from Appendix D. (cfs x 0.645 = MGD)

	Interim Outfall 001 	+	Beaver Creek Between 001 and 002	==>	Resulting Beaver Above 002	+	Outfall 002 		Resulting Beaver Below 002	+	Beaver Creek Between 002 and Falls	==>	Resulting Beaver at Falls	+	Beaver Creek Between Falls and Mouth	==>	Resulting Beaver Above Confluence
Flows (MGD)																	
Low	0.25		0.05		0.30		0.01		0.31		0.05		0.36		0.03		0.39
Average	11.94		2.58		14.52		0.17		14.69		2.46		17.15		1.52		18.67
pH	7.0		6.1				7.0				6.1				6.1		

First Approximation of pH Alterations

Low

$[0.25(10^{-7}) + 0.05(8x10^{-7})] / [0.30] = 2.17x10^{-7}$ ==> 6.7 ==> Resulting Beaver Above 002
$[0.30(2.17x10^{-7}) + 0.01(10^{-7})] / [0.031] = 2.13x10^{-7}$ ==> 6.7 ==> Resulting Beaver Below 002
$[0.31(2.13x10^{-7}) + 0.05(8x10^{-7})] / [0.36] = 2.95x10^{-7}$ ==> 6.5 ==> Resulting Beaver at Falls
$[0.36(2.95x10^{-7}) + 0.03(8x10^{-7})] / [0.39] = 3.34x10^{-7}$ ==> 6.5 ==> Resulting Beaver Above Confluence

Average

$[11.94(10^{-7}) + 2.58(8x10^{-7})] / [14.52] = 2.24x10^{-7}$ ==> 6.6 ==> Resulting Beaver Above 002
$[14.52(2.24x10^{-7}) + 0.17(10^{-7})] / [14.69] = 2.23x10^{-7}$ ==> 6.7 ==> Resulting Beaver Below 002
$[14.69(2.23x10^{-7}) + 2.46(8x10^{-7})] / [17.15] = 3.05x10^{-7}$ ==> 6.5 ==> Resulting Beaver at Falls
$[17.15(3.05x10^{-7}) + 1.52(8x10^{-7})] / [18.67] = 3.46x10^{-7}$ ==> 6.5 ==> Resulting Beaver Above Confluence

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TABLE III-4
SCENARIO NO. 1 - BEAVER CREEK AT YEAR 6
RESULTING WATER QUALITY CHARACTERISTICS OF LOWER BEAVER CREEK AND THE BLOSSOM RIVER
DUE TO DISCHARGES FROM THE INTERIM BEAVER CREEK AND PERSONNEL HOUSING AREA WATER QUALITY CONTROL FACILITIES 1/

Parameter (mg/l or as noted)	Outfall 001 Discharge 2/	Beaver Creek Existing Water Quality Mean 3/	Projected Water Quality At Low Flow		Blossom River Existing Water Quality Mean 4/	Proposed Alaska Receiving Water Quality Standards 5/	Projected Water Quality At Average Flow	
			Beaver Creek Below 002	Beaver Creek Confluence			Beaver Creek Below 002	Beaver Creek Confluence
Suspended solids	20.0	5.2	17.6	15.1	1.0	6/	17.4	14.8
Temperature, °C	No change	5.6	No change	No change	5.2	<15	No change	No change
Dissolved oxygen	10.0	11.7	10.2	10.5	11.8	>7.0	10.3	10.6
Total dissolved solids	196.0	22.0	177.7	145.8	19.2	7/	168.9	137.6
pH, units	7.0	6.1	6.7	6.5	6.1	6.5-8.5	6.7	6.5
Total hardness, as $CaCO_3$	79.0	9.7	71.7	59.0	11.3	-	68.2	55.7
Alkalinity, as $CaCO_3$	61.9	11.4	56.6	47.3	8.7	>20.0	54.0	44.9
Oil and grease	4.6	0.3	4.1	3.3	0.7	8/	3.9	3.1
Total organic carbon	7.8	2.5	7.2	6.2	7.9	-	7.0	6.0
NH_3 + org nitrogen, as N	1.2	0.4	1.1	1.0	0.4	-	1.1	0.9
Nitrate nitrogen, as N	1.49	0.06	1.34	0.11	0.09	<10/-/45	1.27	1.01
Total phosphorus, as P	0.10	0.08	0.10	0.10	0.03	-	0.10	0.09
Silica	8.7	3.4	8.2	7.2	3.1	-	7.9	6.9
Calcium	38.6	3.5	34.9	28.5	4.0	-	33.2	26.8
Sulfate	91.5	6.5	82.6	67.0	3.5	<200/-/500	78.3	63.0
Chloride	3.2	1.0	3.0	2.6	0.9	<200/-/500	2.9	2.5
Arsenic	0.008	<0.005	0.008	<0.007	0.005	0.360/0.190/0.05	0.008	0.007
Cadmium	0.003	<0.002	0.003	0.003	<0.002	0.0039/0.0011/0.010	0.003	0.002
Copper	0.006	<0.003	0.005	0.005	<0.003	0.018/0.012/1.0	0.005	0.005
Iron	0.347	0.145	0.326	0.289	0.079	-/1.0/0.3	0.316	0.279
Lead	0.014	<0.010	0.013	0.013	<0.010	0.082/0.0032/0.05	0.013	<0.012
Manganese	0.184	0.009	0.166	0.134	0.009	-/-/0.05	0.157	0.125
Molybdenum	0.413	<0.020	0.372	0.300	<0.020	-/-/-	0.352	0.281
Zinc	0.016	0.009	0.015	0.014	0.014	0.12/0.11/5.0	0.015	0.014

1/ See Appendix E for assumptions concerning water quality mass balances.
2/ From mass balance.
3/ Data source Table 3-5, Station BV-QC-1890.
4/ Data source Table 3-5, Station BL-QC-1894.
5/ For the trace metal criteria that are determined by the water's hardness, calculations were based on the hardness of 100 mg/l as $CaCO_3$. Where there are multiple values, the first value represents the acute toxicity level, the second value represents the chronic toxicity level, and the third value i the drinking water standard.
6/ Standard is no measurable increase above background. Assumed to be 30/20 mg/l for calculation purposes.
7/ Increase in TDS shall not exceed one-third of the concentration of the natural condition of the water body. Assumed to be <500 mg/l for calculation purposes. Drinking water standard is 1,000 mg/l.
8/ See Appendix E, Table II-1, Parameter 10.

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SCENARIO #1 - BEAVER CREEK AT 6 YEARS
AVERAGE FLOW
RATES OF FLOW IN MILLIONS GPD

	NATURAL RUNOFF +	DISTURBED RUNOFF =	001 OUTFALL +	NATURAL RUNOFF =	BEAVER CREEK ABOVE 002 +	002 OUTFALL =	BEAVER CREEK BELOW 002 +	NATURAL RUNOFF =	BEAVER CREEK AT FALLS +	NATURAL RUNOFF =	BEAVER CREE CONFLUENCE
RATE	7.594	4.346	11.940	2.580	14.520	0.170	14.690	2.460	17.150	1.520	18.670
DISSOLVED OXYGEN	11.700	7.000	9.989	11.700	10.293	7.000	10.255	11.700	10.462	11.700	10.563
TOTAL DISS SOLIDS	22.000	500.000	195.992	22.000	165.076	500.000	168.952	22.000	147.873	22.000	137.625
HARDNESS	9.700	200.000	78.969	9.700	66.661	200.000	68.204	9.700	59.812	9.700	55.732
ALKALINITY	11.400	150.000	61.850	11.400	52.886	150.000	54.010	11.400	47.898	11.400	44.926
OIL & GREASE	0.300	12.000	4.559	0.300	3.802	12.000	3.897	0.300	3.381	0.300	3.130
TOTAL ORG CARBON	2.500	17.000	7.778	2.500	6.840	17.000	6.958	2.500	6.318	2.500	6.007
NH3 & ORG N	0.400	2.600	1.201	0.400	1.059	2.600	1.076	0.400	0.979	0.400	0.932
NITRATE	0.060	4.000	1.494	0.060	1.239	4.000	1.271	0.060	1.098	0.060	1.013
TOTAL P	0.080	0.130	0.098	0.080	0.095	0.130	0.095	0.080	0.093	0.080	0.092
SILICA	3.400	18.000	8.714	3.400	7.770	18.000	7.888	3.400	7.245	3.400	6.932
SULFATE	6.500	240.000	91.494	6.500	76.392	240.000	78.285	6.500	67.988	6.500	62.982
CHLORIDE	1.000	7.000	3.184	1.000	2.796	7.000	2.845	1.000	2.580	1.000	2.451
CALCIUM	3.500	100.000	38.626	3.500	32.385	100.000	33.167	3.500	28.312	3.500	26.843
ARSENIC	0.005	0.014	0.008	0.005	0.008	0.014	0.008	0.005	0.007	0.005	0.007
CADMIUM	0.002	0.004	0.003	0.002	0.003	0.004	0.003	0.002	0.003	0.002	0.002
COPPER	0.003	0.010	0.006	0.003	0.005	0.010	0.005	0.003	0.005	0.003	0.005
IRON	0.145	0.700	0.347	0.145	0.311	0.700	0.316	0.145	0.291	0.145	0.279
LEAD	0.010	0.020	0.014	0.010	0.013	0.020	0.013	0.010	0.013	0.010	0.012
MAGANESE	0.009	0.490	0.184	0.009	0.153	0.490	0.157	0.009	0.136	0.009	0.125
MOLYBDENUM	0.020	1.100	0.413	0.020	0.343	1.100	0.352	0.020	0.304	0.020	0.281
ZINC	0.009	0.028	0.016	0.009	0.015	0.028	0.015	0.009	0.014	0.009	0.014
SUSPENDED SOLIDS	5.200	45.859	20.000	5.200	17.370	20.000	17.401	5.200	15.651	5.200	14.800

SCENARIO #1 - BEAVER CREEK AT 6 YEARS
LOW FLOW
RATES OF FLOW IN MILLIONS GPD

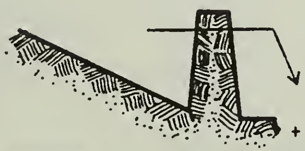
	NATURAL RUNOFF +	DISTURBED RUNOFF =	001 OUTFALL +	NATURAL RUNOFF =	BEAVER CREEK ABOVE 002 +	002 OUTFALL =	BEAVER CREEK BELOW 002 +	NATURAL RUNOFF =	BEAVER CREEK AT FALLS +	NATURAL RUNOFF =	BEAVER CREEK CONFLUENCE
RATE	0.159	0.091	0.250	0.050	0.300	0.010	0.310	0.050	0.360	0.030	0.390
DISSOLVED OXYGEN	11.700	7.000	9.989	11.700	10.274	7.000	10.169	11.700	10.381	11.700	10.483
TOTAL DISS SOLIDS	22.000	500.000	195.992	22.000	166.993	500.000	177.735	22.000	156.106	22.000	145.790
HARDNESS	9.700	200.000	78.969	9.700	67.424	200.000	71.701	9.700	63.090	9.700	58.983
ALKALINITY	11.400	150.000	61.850	11.400	53.442	150.000	56.557	11.400	50.285	11.400	47.294
OIL & GREASE	0.300	12.000	4.559	0.300	3.849	12.000	4.112	0.300	3.583	0.300	3.330
TOTAL ORG CARBON	2.500	17.000	7.778	2.500	6.898	17.000	7.224	2.500	6.568	2.500	6.255
NH3 & ORG N	0.400	2.600	1.201	0.400	1.067	2.600	1.117	0.400	1.017	0.400	0.970
NITRATE	0.060	4.000	1.494	0.060	1.255	4.000	1.344	0.060	1.165	0.060	1.080
TOTAL P	0.080	0.130	0.098	0.080	0.095	0.130	0.096	0.080	0.094	0.080	0.093
SILICA	3.400	18.000	8.714	3.400	7.829	18.000	8.157	3.400	7.496	3.400	7.181
SULFATE	6.500	240.000	91.494	6.500	77.328	240.000	82.576	6.500	72.010	6.500	66.971
CHLORIDE	1.000	7.000	3.184	1.000	2.820	7.000	2.955	1.000	2.683	1.000	2.554
CALCIUM	3.500	100.000	38.626	3.500	32.772	100.000	34.940	3.500	30.574	3.500	28.491
ARSENIC	0.005	0.014	0.008	0.005	0.008	0.014	0.008	0.005	0.008	0.005	0.007
CADMIUM	0.002	0.004	0.003	0.002	0.003	0.004	0.003	0.002	0.003	0.002	0.003
COPPER	0.003	0.010	0.006	0.003	0.005	0.010	0.005	0.003	0.005	0.003	0.005
IRON	0.145	0.700	0.347	0.145	0.313	0.700	0.326	0.145	0.301	0.145	0.289
LEAD	0.010	0.020	0.014	0.010	0.013	0.020	0.013	0.010	0.013	0.010	0.013
MAGANESE	0.009	0.490	0.184	0.009	0.155	0.490	0.166	0.009	0.144	0.009	0.134
MOLYBDENUM	0.020	1.100	0.413	0.020	0.348	1.100	0.372	0.020	0.323	0.020	0.300
ZINC	0.009	0.028	0.016	0.009	0.015	0.028	0.015	0.009	0.014	0.009	0.014
SUSPENDED SOLIDS	5.200	45.859	20.000	5.200	17.533	20.000	17.613	5.200	15.889	5.200	15.067

RESULTING WATER QUALITY CHARACTERISTICS OF SCENARIO NO. 2 - BEAVER CREEK AT YEAR 55

Resulting water quality characteristics for this scenario are provided in Table III-5.

Assumptions

1. Influent from disturbed areas into the final water quality control facility in lower Beaver Creek, Outfall 001, will have the water quality characteristics as presented in Table III-1.
2. The discharge from the personnel housing area, Outfall 002, is upstream of final Outfall 001 and therefore is included in the final Outfall 001 flows.
3. Natural runoff from the portions of the drainage basin between the final water quality control facility, Outfall C01, and the Beaver Creek Falls and between the falls and the mouth of Beaver Creek makes up the remainder of lower Beaver Creek flow and have Beaver Creek (BV-QC-1890) baseline water quality.
4. The resulting water quality of the Blossom River below the confluence with Beaver Creek is obtained by a mass balance of resulting lower Beaver Creek and Blossom River (BL-QC-1894) baseline water quality parameters.
5. Average annual flows and 7-day, 10-year low flows were obtained from Appendix D. (cfs x .645 = MGD)



	Final Outfall 001 +	Beaver Creek Between 001 and Falls ==>	Resulting Beaver At Falls +	Beaver Creek Between Falls and Mouth ==>	Resulting Beaver at Mouth +	Blossom River Above Confluence ==>	Resulting Blossom Below Beaver
Flows (MGD)							
Low	0.31	0.05	0.36	0.03	0.39	24.39	24.78
Average	14.70	2.46	17.16	1.52	18.68	424.52	443.20
pH	7.0	6.1		6.1		6.1	

First Approximation of pH Alterations

Low

$[0.31(10^{-7}) + 0.05(8x10^{-7})] / [0.36] = 1.97x10^{-7}$ ==> 6.7 ==> Resulting Beaver at Falls
$[0.36(1.97x10^{-7}) + 0.03(8x10^{-7})] / [0.39] = 2.44x10^{-7}$ ==> 6.6 ==> Resulting Beaver at Mouth
$[0.39(2.44x10^{-7}) + 24.39(8x10^{-7})] / [24.78] = 7.91x10^{-7}$ ==> 6.1 ==> Resulting Blossom Below Beaver

Average

$[14.70(10^{-7}) + 2.46(8x10^{-7})] / [17.16] = 2.00x10^{-7}$ ==> 6.7 ==> Resulting Beaver at Falls
$[17.16(2.00x10^{-7}) + 1.52(8x10^{-7})] / [18.68] = 2.49x10^{-7}$ ==> 6.6 ==> Resulting Beaver at Mouth
$[18.68(2.49x10^{-7}) + 424.52(8.10^{-7}) / [443.20] = 7.77x10^{-7}$ ==> 6.1 ==> Resulting Blossom Below Beaver

TABLE III-5

SCENARIO NO. 2 - BEAVER CREEK AT YEAR 55

RESULTING WATER QUALITY CHARACTERISTICS OF LOWER BEAVER CREEK AND THE BLOSSOM RIVER DUE TO DISCHARGES FROM THE FINAL BEAVER CREEK WATER QUALITY CONTROL FACILITIES 1/

Parameter (mg/l or as noted)	Outfall 001 Discharge 2/	Beaver Creek Existing Water Quality Mean 3/	Projected Water Quality At Low Flow		Blossom River Existing Water Quality Mean 4/	Proposed Alaska Receiving Water Quality Standards 5/	Projected Water Quality At Average Flow	
			Beaver Creek At Falls	Blossom River Below Beaver Creek			Beaver Creek At Falls	Blossom River Below Beaver Creek
Suspended solids	20.0	5.2	17.9	1.3	1.0	6/	17.9	1.7
Temperature, °C	No change	5.6	No change	No change	5.2	<15	No change	No change
Dissolved oxygen	7.5	11.7	8.1	11.7	11.8	>7.0	8.1	11.7
Total dissolved solids	452.2	22.0	392.5	24.6	19.2	7/	390.5	33.6
pH, units	7.0	6.1	6.7	6.1	6.1	6.5-8.5	6.7	6.1
Total hardness, as $CaCO_3$	181.0	9.7	157.2	13.4	11.3	-	156.4	16.9
Alkalinity, as $CaCO_3$	136.1	11.4	118.8	10.3	8.7	>20.0	118.3	13.0
Oil and grease	10.8	0.3	9.4	0.8	0.7	8/	9.3	1.0
Total organic carbon	15.6	2.5	13.7	8.0	7.9	-	13.7	8.1
NH_3 + org nitrogen, as N	2.4	0.4	2.1	0.4	0.4	-	2.1	0.5
Nitrate nitrogen, as N	3.61	0.06	3.11	0.13	0.09	<10/-/45	3.10	0.21
Total phosphorus, as P	0.13	0.08	0.12	0.03	0.03	-	0.12	0.03
Silica	16.5	3.4	14.7	3.3	3.1	-	14.7	3.5
Calcium	90.4	3.5	78.3	5.1	4.0	-	77.9	6.9
Sulfate	216.7	6.5	187.5	6.2	3.5	<200/-/500	186.5	10.6
Chloride	6.4	1.0	5.7	1.0	0.9	<200/-/500	5.6	1.1
Arsenic	0.013	<0.005	0.012	<0.005	<0.005	0.360/0.190/0.05	0.012	<0.005
Cadmium	0.004	<0.002	0.004	<0.002	<0.002	0.0039/0.0011/0.010	0.004	<0.002
Copper	0.009	<0.003	0.008	<0.003	<0.003	0.018/0.012/1.0	0.008	<0.003
Iron	0.645	0.145	0.575	0.086	0.079	-/1.0/0.3	0.573	0.098
Lead	0.019	<0.010	0.018	<0.010	<0.010	0.082/0.0032/0.05	0.018	<0.010
Manganese	0.442	0.009	0.382	0.014	0.009	-/-/0.05	0.380	0.023
Molybdenum	0.992	<0.020	0.857	0.038	<0.026	-/-/-	0.853	0.058
Zinc	0.026	0.009	0.024	0.014	0.014	0.12/0.11/5.0	0.024	0.014

1/ See Appendix E for assumptions concerning water quality mass balances.
2/ From mass balance.
3/ Data source Table 3-5, Station BV-QC-1890.
4/ Data source Table 3-5, Station BL-QC-1894.
5/ For the trace metal criteria that are determined by the water's hardness, calculations were based on the hardness of 100 mg/l as $CaCO_3$. Where there are multiple values, the first value represents the acute toxicity level, the second value represents the chronic toxicity level, and the third value is the drinking water standard.
6/ Standard is no measurable increase above background. Assumed to be 30/20 mg/l for calculation purposes.
7/ Increase in TDS shall not exceed one-third of the concentration of the natural condition of the water body. Assumed to be <500 mg/l for calculation purposes. Drinking water standard is 1,000 mg/l.
8/ See Appendix E, Table II-1, Parameter 10.

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SCENARIO #2 - BEAVER CREEK AT 55 YEARS
AVERAGE FLOW
FLOW RATES IN MILLIONS OF GPD

	NATURAL RUNOFF	+	DISTURBED RUNOFF	=	001 OUTFALL	+	NATURAL RUNOFF	=	BEAVER CREEK AT FALLS	+	NATURAL RUNOFF	=	BEAVER CREEK CONFLUENCE	+	NATURAL RUNOFF	=	BLOSSOM CONFLUENCE
RATE	1.470		13.230		14.700		2.460		17.160		1.520		18.680		424.516		443.196
DISSOLVED OXYGEN	11.700		7.000		7.470		11.700		8.076		11.700		8.371		11.800		11.655
TOTAL DISS SOLIDS	22.000		500.000		452.200		22.000		390.528		22.000		360.541		19.200		33.587
HARDNESS	9.700		200.000		180.970		9.700		156.417		9.700		144.479		11.300		16.913
ALKALINITY	11.400		150.000		136.140		11.400		118.258		11.400		109.563		8.700		12.951
OIL & GREASE	0.300		12.000		10.830		0.300		9.320		0.300		8.586		0.700		1.032
TOTAL ORG CARBON	2.500		17.000		15.550		2.500		13.679		2.500		12.770		7.900		8.105
NH3 & ORG N	0.400		2.600		2.380		0.400		2.096		0.400		1.958		0.400		0.466
NITRATE	0.060		4.000		3.606		0.060		3.098		0.060		2.850		0.090		0.206
TOTAL P	0.080		0.130		0.125		0.080		0.119		0.080		0.115		0.030		0.034
SILICA	3.400		18.000		16.540		3.400		14.656		3.400		13.740		3.100		3.548
SULFATE	6.500		240.000		216.650		6.500		186.524		6.500		171.875		3.500		10.597
CHLORIDE	1.000		7.000		6.400		1.000		5.626		1.000		5.249		0.900		1.083
CALCIUM	3.500		100.000		90.350		3.500		77.899		3.500		71.846		4.000		6.860
ARSENIC	0.005		0.014		0.013		0.005		0.012		0.005		0.011		0.005		0.005
CADMIUM	0.002		0.004		0.004		0.002		0.004		0.002		0.003		0.002		0.002
COPPER	0.003		0.010		0.009		0.003		0.008		0.003		0.008		0.003		0.003
IRON	0.145		0.700		0.645		0.145		0.573		0.145		0.538		0.079		0.098
LEAD	0.010		0.020		0.019		0.010		0.018		0.010		0.017		0.010		0.010
MANGANESE	0.009		0.490		0.442		0.009		0.380		0.009		0.350		0.009		0.023
MOLYBDENUM	0.020		1.100		0.992		0.020		0.853		0.020		0.785		0.026		0.058
ZINC	0.009		0.028		0.026		0.009		0.024		0.009		0.022		0.014		0.014
SUSPENDED SOLIDS	5.200		21.644		20.000		5.200		17.878		5.200		16.846		1.000		1.668

SCENARIO #2 - BEAVER CREEK AT 55 YEARS
LOW FLOW
FLOW RATES IN MILLIONS OF GPD

	NATURAL RUNOFF	+	DISTURBED RUNOFF	=	001 OUTFALL	+	NATURAL RUNOFF	=	BEAVER CREEK AT FALLS	+	NATURAL RUNOFF	=	BEAVER CREEK CONFLUENCE	+	NATURAL RUNOFF	=	BLOSSOM CONFLUENCE
RATE	0.031		0.279		0.310		0.050		0.360		0.030		0.390		24.387		24.777
DISSOLVED OXYGEN	11.700		7.000		7.470		11.700		8.057		11.700		8.338		11.800		11.746
TOTAL DISS SOLIDS	22.000		500.000		452.200		22.000		392.450		22.000		363.954		19.200		24.627
HARDNESS	9.700		200.000		180.970		9.700		157.182		9.700		145.838		11.300		13.418
ALKALINITY	11.400		150.000		136.140		11.400		118.815		11.400		110.552		8.700		10.303
OIL & GREASE	0.300		12.000		10.830		0.300		9.367		0.300		8.670		0.700		0.825
TOTAL ORG CARBON	2.500		17.000		15.550		2.500		13.737		2.500		12.873		7.900		7.978
NH3 & ORG N	0.400		2.600		2.380		0.400		2.105		0.400		1.974		0.400		0.425
NITRATE	0.060		4.000		3.606		0.060		3.114		0.060		2.879		0.090		0.134
TOTAL P	0.080		0.130		0.125		0.080		0.119		0.080		0.116		0.030		0.031
SILICA	3.400		18.000		16.540		3.400		14.715		3.400		13.845		3.100		3.269
SULFATE	6.500		240.000		216.650		6.500		187.462		6.500		173.542		3.500		6.177
CHLORIDE	1.000		7.000		6.400		1.000		5.650		1.000		5.292		0.900		0.969
CALCIUM	3.500		100.000		90.350		3.500		78.287		3.500		72.535		4.000		5.079
ARSENIC	0.005		0.014		0.013		0.005		0.012		0.005		0.011		0.005		0.005
CADMIUM	0.002		0.004		0.004		0.002		0.004		0.002		0.003		0.002		0.002
COPPER	0.003		0.010		0.009		0.003		0.008		0.003		0.008		0.003		0.003
IRON	0.145		0.700		0.644		0.145		0.575		0.145		0.542		0.079		0.086
LEAD	0.010		0.020		0.019		0.010		0.018		0.010		0.017		0.010		0.010
MANGANESE	0.009		0.490		0.442		0.009		0.382		0.009		0.353		0.009		0.014
MOLYBDENUM	0.020		1.100		0.992		0.020		0.857		0.020		0.793		0.026		0.038
ZINC	0.009		0.028		0.026		0.009		0.024		0.009		0.023		0.014		0.014
SUSPENDED SOLIDS	5.200		21.644		20.000		5.200		17.944		5.200		16.964		1.000		1.251

RESULTING WATER QUALITY CHARACTERISTICS OF SCENARIO NO. 3 - WHITE/HILL CREEK AT YEAR 15

Resulting water quality characteristics for this scenario are provided in Table III-6.

Assumptions

1. Influent from disturbed areas into the interim water quality control facility in White Creek, Outfall 003, will have the water quality characteristics as presented in Table III-1.
2. The White Creek interim water quality control facility is located almost down to the confluence with Hill Creek, therefore no natural baseline drainage from White Creek will be considered below the Outfall 003, just the discharge.
3. The resulting water quality of Hill Creek just below the confluence with White Creek is obtained from a mass balance of discharge from Outfall 003 in White Creek and upper Hill Creek (HC-CC-1865) baseline water quality parameters.
4. Natural runoff makes up the remainder of lower Hill Creek flow and has Hill Creek (HC-QC-1865) baseline water quality.
5. Average annual flows and 7-day, 10-year low flows were obtained from Appendix D. (cfs x .645 = MGD)

	Interim Outfall 003 +	Hill Creek Above Confluence ==>	Resulting Hill Below White +	Hill Creek Between White and Falls ==>	Resulting Hill at Falls +	Hill Creek Between Falls and Mouth ==>	Resulting Hill Creek Above Confluence
Flows (MGD)							
Low	0.78	1.30	2.08	1.53	3.61	0.14	3.75
Average	21.72	36.19	57.91	42.71	100.62	3.76	104.38
pH	7.0	6.1		6.1		6.1	

First Approximation of pH Alterations

Low

$[0.78(10^{-7}) + 1.30(8x10^{-7})] / [2.08] = 5.38x10^{-7}$ ==> 6.3 ==> Resulting Hill Below White
$[2.08(5.38x10^{-7}) + 1.53(8x10^{-7})] / [3.61] = 6.49x10^{-7}$ ==> 6.2 ==> Resulting Hill at Falls
$[3.61(6.49x10^{-7}) + 0.14(8x10^{-7})] / [3.75] = 6.54x10^{-7}$ ==> 6.2 ==> Resulting Hill Above Confluence

Average

$[21.72(10^{-7}) + 36.19(8x10^{-7})] / [57.91] = 5.37x10^{-7}$ ==> 6.3 ==> Resulting Hill Below White
$[57.91(5.37x10^{-7}) + 42.71(8x10^{-7})] / [100.62] = 6.49x10^{-7}$ ==> 6.2 ==> Resulting Hill at Falls
$[100.62(6.49x10^{-7}) + 3.76(8x10^{-7})] / [104.38] = 6.54x10^{-7}$ ==> 6.2 ==> Resulting Hill Above Confluence

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TABLE III-6

SCENARIO NO. 3 - WHITE/HILL CREEK AT YEAR 15
RESULTING WATER QUALITY CHARACTERISTICS OF LOWER HILL CREEK AND THE KETA RIVER
DUE TO DISCHARGES FROM THE INTERIM WHITE CREEK WATER QUALITY CONTROL FACILITIES 1/

Parameter (mg/l or as noted)	Outfall 003 Discharge 2/	Hill Creek Existing Water Quality Mean 3/	Projected Water Quality At Low Flow: Hill Creek At Falls	Projected Water Quality At Low Flow: Hill Creek Confluence	Keta River Existing Water Quality Mean 4/	Proposed Alaska Receiving Water Quality Standards 5/	Projected Water Quality At Average Flow: Hill Creek At Falls	Projected Water Quality At Average Flow: Hill Creek Confluence
Suspended solids	20	1.0	5.1	5.0	1.3	6/	5.1	5.0
Temperature, °C	No change	4.8	No change	No change	5.6	<15	No change	No change
Dissolved oxygen	9.2	11.9	11.3	11.3	11.6	>7.0	11.3	11.3
Total dissolved solids	286.1	11.9	71.1	68.9	19.6	7/	71.1	69.0
pH, units	7.0	6.1	6.2	6.2	6.3	6.5-8.5	6.2	6.2
Total hardness, as $CaCO_3$	116.7	6.3	30.2	29.3	8.2	-	30.1	29.3
Alkalinity, as $CaCO_3$	83.8	11.3	27.0	26.4	12.4	>20.0	26.9	26.4
Oil and grease	6.6	0.8	2.1	2.0	0.1	8/	2.1	2.0
Total organic carbon	10.9	2.4	4.2	4.2	2.8	-	4.2	4.2
NH_3 + org nitrogen, as N	1.6	0.5	0.7	0.7	0.4	-	0.7	0.7
Nitrate nitrogen, as N	2.18	0.13	0.57	0.56	0.16	<10/-/45	0.57	0.56
Total phosphorus, as P	0.10	0.10	0.10	0.10	0.10	-	0.10	0.10
Silica	11.9	2.6	4.6	4.5	2.8	-	4.6	4.5
Calcium	57.3	2.2	14.1	13.7	2.8	-	14.1	13.7
Sulfate	137.0	2.8	31.8	30.7	3.2	<200/-/500	31.8	30.7
Chloride	4.2	1.0	1.7	1.7	1.0	<200/-/500	1.7	1.7
Arsenic	0.010	<0.005	0.006	0.006	<0.005	0.360/0.190/0.05	0.006	0.006
Cadmium	0.002	<0.002	0.002	<0.002	<0.002	0.0039/0.0011/0.010	<0.002	
Copper	0.007	<0.003	0.004	0.004	<0.003	0.018/0.012/1.0	0.004	0.004
Iron	0.399	0.055	0.129	0.126	0.068	-/1.0/0.3	0.129	0.127
Lead	0.011	<0.010	0.010	<0.010	<0.010	0.082/0.0032/0.05	0.010	<0.010
Manganese	0.269	0.007	0.064	0.061	0.005	-/-/0.05	0.063	0.061
Molybdenum	0.603	<0.020	0.146	0.141	<0.020	-/-/-	0.146	0.141
Zinc	0.022	0.008	0.011	0.011	0.006	0.12/0.11/5.0	0.011	0.011

1/ See Appendix E for assumptions concerning water quality mass balances.
2/ From mass balance.
3/ Data source Table 3-5, Station BV-QC-1890.
4/ Data source Table 3-5, Station BL-QC-1894.
5/ For the trace metal criteria that are determined by the water's hardness, calculations were based on the hardness of 100 mg/l as $CaCO_3$. Where there are multiple values, the first value represents the acute toxicity level, the second value represents the chronic toxicity level, and the third value i the drinking water standard.
6/ Standard is no measurable increase above background. Assumed to be 30/20 mg/l for calculation purposes.
7/ Increase in TDS shall not exceed one-third of the concentration of the natural condition of the water body. Assumed to be <500 mg/l for calculation purposes. Drinking water standard is 1,000 mg/l.
8/ See Appendix E, Table II-1, Parameter 10.

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SCENARIO #3 - WHITE/HILL CREEKS AT 15 YEARS
AVERAGE FLOW
FLOW RATES IN MILLIONS OF GPD

	NATURAL RUNOFF +	DISTURBED RUNOFF =	003 OUTFALL +	HILL CREEK ABOVE 003 =	HILL CREEK BELOW 003 +	NATURAL RUNOFF =	HILL CREEK AT FALLS +	NATURAL RUNOFF =	HILL CREEK AT CONFLUENCE
RATE	9.991	11.729	21.720	36.190	57.910	42.710	100.620	3.760	104.380
DISSOLVED OXYGEN	11.800	7.000	9.208	11.900	10.890	11.900	11.319	11.900	11.340
TOTAL DISS SOLIDS	35.000	500.000	286.100	11.900	114.743	11.900	71.089	11.900	68.957
HARDNESS	19.000	200.000	116.740	6.300	47.722	6.300	30.140	6.300	29.281
ALKALINITY	6.000	150.000	83.760	11.300	38.477	11.300	26.941	11.300	26.378
OIL & GREASE	0.300	12.000	6.618	0.800	2.982	0.800	2.056	0.800	2.011
TOTAL ORG CARBON	3.700	17.000	10.882	2.400	5.581	2.400	4.231	2.400	4.165
NH3 & ORG N	0.500	2.600	1.634	0.500	0.925	0.500	0.745	0.500	0.736
NITRATE	0.050	4.000	2.183	0.130	0.900	0.130	0.573	0.130	0.557
TOTAL P	0.070	0.130	0.102	0.100	0.101	0.100	0.101	0.100	0.100
SILICA	4.800	18.000	11.928	2.600	6.099	2.600	4.614	2.600	4.541
SULFATE	16.000	240.000	136.960	2.800	53.119	2.800	31.760	2.800	30.717
CHLORIDE	0.900	7.000	4.194	1.000	2.198	1.000	1.689	1.000	1.665
CALCIUM	7.200	100.000	57.312	2.200	22.871	2.200	14.097	2.200	13.668
ARSENIC	0.005	0.014	0.010	0.005	0.007	0.005	0.006	0.005	0.006
CADMIUM	0.000	0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.002
COPPER	0.003	0.010	0.007	0.003	0.004	0.003	0.004	0.003	0.004
IRON	0.045	0.700	0.399	0.055	0.184	0.055	0.129	0.055	0.127
LEAD	0.000	0.020	0.011	0.010	0.010	0.010	0.010	0.010	0.010
MAGANESE	0.009	0.490	0.269	0.007	0.105	0.007	0.063	0.007	0.061
MOLYBDENUM	0.020	1.100	0.603	0.020	0.239	0.020	0.146	0.020	0.141
ZINC	0.015	0.028	0.022	0.008	0.013	0.008	0.011	0.008	0.011
SUSPENDED SOLIDS	1.000	36.185	20.000	1.000	8.126	1.000	5.101	1.000	4.954

SCENARIO #3 - WHITE/HILL CREEKS AT 15 YEARS
LOW FLOW
FLOW RATES IN MILLIONS OF GPD

	NATURAL RUNOFF	+	DISTURBED RUNOFF	=	003 OUTFALL	+	HILL CREEK ABOVE 003	=	HILL CREEK BELOW 003	+	NATURAL RUNOFF	=	HILL CREEK AT FALLS	+	NATURAL RUNOFF	=	HILL CREEK AT CONFLUENCE
RATE	0.359		0.421		0.780		1.300		2.080		1.530		3.610		0.140		3.750
DISSOLVED OXYGEN	11.800		7.000		9.208		11.900		10.891		11.900		11.318		11.900		11.340
TOTAL DISS SOLIDS	35.000		500.000		286.100		11.900		114.725		11.900		71.145		11.900		68.934
HARDNESS	19.000		200.000		116.740		6.300		47.715		6.300		30.162		6.300		29.272
ALKALINITY	6.000		150.000		83.760		11.300		38.473		11.300		26.956		11.300		26.372
OIL & GREASE	0.300		12.000		6.618		0.800		2.982		0.800		2.057		0.800		2.010
TOTAL ORG CARBON	3.700		17.000		10.882		2.400		5.581		2.400		4.233		2.400		4.164
NH3 & ORG N	0.500		2.600		1.634		0.500		0.925		0.500		0.745		0.500		0.736
NITRATE	0.050		4.000		2.183		0.130		0.900		0.130		0.574		0.130		0.557
TOTAL P	0.070		0.130		0.102		0.100		0.101		0.100		0.101		0.100		0.100
SILICA	4.800		18.000		11.928		2.600		6.098		2.600		4.615		2.600		4.540
SULFATE	16.000		240.000		136.960		2.800		53.110		2.800		31.787		2.800		30.705
CHLORIDE	0.900		7.000		4.194		1.000		2.198		1.000		1.690		1.000		1.664
CALCIUM	7.200		100.000		57.312		2.200		22.867		2.200		14.108		2.200		13.663
ARSENIC	0.005		0.014		0.010		0.005		0.007		0.005		0.006		0.005		0.006
CADMIUM	0.000		0.004		0.002		0.002		0.002		0.002		0.002		0.002		0.002
COPPER	0.003		0.010		0.007		0.003		0.004		0.003		0.004		0.003		0.004
IRON	0.045		0.700		0.399		0.055		0.184		0.055		0.129		0.055		0.126
LEAD	0.000		0.020		0.011		0.010		0.010		0.010		0.010		0.010		0.010
MAGANESE	0.009		0.490		0.269		0.007		0.105		0.007		0.064		0.007		0.061
MOLYBDENUM	0.020		1.100		0.603		0.020		0.239		0.020		0.146		0.020		0.141
ZINC	0.015		0.028		0.022		0.008		0.013		0.008		0.011		0.008		0.011
SUSPENDED SOLIDS	1.000		36.185		20.000		1.000		8.125		1.000		5.105		1.000		4.952

RESULTING WATER QUALITY CHARACTERISTICS OF SCENARIO NO. 4 - HILL CREEK AT YEAR 55

Resulting water quality characteristics for this scenario are provided in Table III-7.

Assumptions

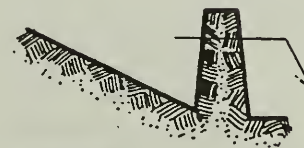
1. Influent from disturbed areas into the final water quality control facility in Hill Creek, Outfall 003, will have the water quality characteristics as presented in Table III-1.

2. The flow in Hill Creek just below the final water quality control facility, Outfall 003, is essentially what was discharged.

3. Natural runoff from the portions of the drainage basin between Outfall 003 and the lower Hill Creek falls, and the falls and the mouth of Hill Creek make up the remainder of lower Hill Creek flow and have Hill Creek (HC-QC-1865) baseline water quality.

4. The resulting water quality of the Keta River below the confluence with Hill Creek is obtained by a mass balance of resulting lower Hill Creek and Keta River (KE-QC-1860) baseline water quality parameters.

5. Average annual flows and 7-day, 10-year low flows were obtained from Appendix D. (cfs x .645 = MGD)



	Final Outfall 003	+	Hill Creek Between 003 and Falls	==>	Resulting Hill Below Falls	+	Hill Creek Between Falls and Mouth	==>	Resulting Hill at Mouth	+	Keta River Above Confluence	==>	Resulting Keta Below Hill
Flows (MGD)													
Low	3.17		0.44		3.61		0.14		3.75		22.97		26.72
Average	88.31		12.31		10C.62		3.76		104.38		394.84		499.22
pH	7.0		6.1				6.1				6.3		

First Approximation of pH Alterations

Low

$[3.17(10^{-7}) + 0.44(8x10^{-7})] / [3.61] = 1.85x10^{-7}$ ==> 6.7 ==> Resulting Hill at Falls
$[3.61(1.85x10^{-7}) + 0.14(8x10^{-7})] / [3.75] = 2.08x10^{-7}$ ==> 6.7 ==> Resulting Hill Above Confluence
$[3.75(2.08x10^{-7}) + 22.97(5x10^{-7}) / [26.72] = 4.59x1C^{-7}$ ==> 6.3 ==> Resulting Keta Below Hill

Average

$[88.31(10^{-7}) + 12.31(8x10^{-7})] / [100.62] = 1.86x10^{-7}$ ==> 6.7 ==> Resulting Hill at Falls
$[100.62(1.86x10^{-7}) + 3.76(8x10^{-7})] / [104.38] = 2.08x10^{-7}$ ==> 6.7 ==> Resulting Hill Above Confluence
$[104.38(2.08x10^{-7}) + 394.84(5x10^{-7})] / [499.22] = 4.39x10^{-7}$ ==> 6.4 ==> Resulting Keta Below Hill

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TABLE III-7
SCENARIO NO. 4 - HILL CREEK AT YEAR 55
RESULTING WATER QUALITY CHARACTERISTICS OF LOWER HILL CREEK AND THE KETA RIVER
DUE TO DISCHARGES FROM THE FINAL HILL CREEK WATER QUALITY CONTROL FACILITIES 1/

Parameter (mg/l or as noted)	Outfall 003 Discharge 2/	Hill Creek Existing Water Quality Mean 3/	Projected Water Quality At Low Flow: Hill Creek At Falls	Projected Water Quality At Low Flow: Keta River Below Hill Creek	Keta River Existing Water Quality Mean 4/	Proposed Alaska Receiving Water Quality Standards 5/	Projected Water Quality At Average Flow: Hill Creek At Falls	Projected Water Quality At Average Flow: Keta River Below Hill Creek
Suspended solids	20	1.0	17.7	3.5	1.3	6/	17.7	4.6
Temperature, °C	No change	4.8	No change	No change	5.6	<15	No change	No change
Dissolved oxygen	10.9	11.9	11.0	11.5	11.6	>7.0	11.0	11.5
Total dissolved solids	114.4	11.9	101.9	30.7	19.6	7/	101.9	36.1
pH, units	7.0	6.1	6.7	6.4	6.3	6.5-8.5	6.7	6.3
Total hardness, as $CaCO_3$	47.0	6.3	42.0	12.8	8.2	-	42.0	15.0
Alkalinity, as $CaCO_3$	40.4	11.3	36.9	15.7	12.4	>20.0	36.9	17.3
Oil and grease	3.2	0.8	2.9	0.5	0.1	8/	2.9	0.7
Total organic carbon	5.5	2.4	5.1	3.1	2.8	-	5.1	3.3
NH_3 + org nitrogen, as N	0.9	0.5	0.9	0.5	0.4	-	0.9	0.5
Nitrate nitrogen, as N	0.94	0.13	0.84	0.25	0.16	<10/-/45	0.84	0.30
Total phosphorus, as P	0.11	0.10	0.11	0.10	0.10	-	0.12	0.10
Silica	5.8	2.6	5.4	3.2	2.8	-	5.4	3.3
Calcium	22.7	2.2	20.2	5.2	2.8	-	20.2	6.3
Sulfate	52.6	2.8	46.5	9.1	3.2	<200/-/500	46.5	11.9
Chloride	2.3	1.0	2.1	1.1	1.0	<200/-/500	2.1	1.2
Arsenic	0.007	<0.005	0.007	0.005	<0.005	0.360/0.190/0.05	0.007	0.005
Cadmium	0.002	<0.002	0.002	<0.002	<0.002	0.0039/0.0011/0.010	<0.002	
Cooper	0.004	<0.003	0.004	0.003	<0.003	0.018/0.012/1.0	0.004	0.003
Iron	0.190	0.055	0.174	0.082	0.068	-/1.0/0.3	0.089	
Lead	0.012	<0.010	0.012	0.010	<0.010	0.082/0.0032/0.05	0.012	0.010
Manganese	0.108	0.007	0.096	0.017	0.005	-/-/0.05	0.096	0.023
Molybdenum	0.247	<0.020	0.219	0.047	<0.020	-/-/-	0.219	0.060
Zinc	0.012	0.008	0.012	0.007	0.006	0.12/0.11/5.0	0.012	0.007

1/ See Appendix E for assumptions concerning water quality mass balances.
2/ From mass balance.
3/ Data source Table 3-5, Station BV-QC-1890.
4/ Data source Table 3-5, Station BL-QC-1894.
5/ For the trace metal criteria that are determined by the water's hardness, calculations were based on the hardness of 100 mg/l as $CaCO_3$. Where there are multiple values, the first value represents the acute toxicity level, the second value represents the chronic toxicity level, and the third value is the drinking water standard.
6/ Standard is no measurable increase above background. Assumed to be 30/20 mg/l for calculation purposes.
7/ Increase in TDS shall not exceed one-third of the concentration of the natural condition of the water body. Assumed to be <500 mg/l for calculation purposes. Drinking water standard is 1,000 mg/l.
8/ See Appendix E, Table II-1, Parameter 10.

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SCENARIO #4 - HILL CREEK AT 55 YEARS
AVERAGE FLOW
FLOW RATES IN MILLIONS OF GPD

	NATURAL RUNOFF +	DISTURBED RUNOFF =	003 OUTFALL +	NATURAL RUNOFF =	HILL CREEK AT FALLS +	NATURAL RUNOFF =	HILL CREEK AT CONFLUENCE +	NATURAL RUNOFF =	KETA CONFLUENCE
RATE	69.765	18.545	88.310	12.310	100.620	3.760	104.380	394.839	499.219
DISSOLVED OXYGEN	11.900	7.000	10.871	11.900	10.997	11.900	11.029	11.600	11.481
TOTAL DISS SOLIDS	11.900	500.000	114.401	11.900	101.861	11.900	98.620	19.600	36.122
HARDNESS	6.300	200.000	46.977	6.300	42.001	6.300	40.715	8.200	14.998
ALKALINITY	11.300	150.000	40.427	11.300	36.864	11.300	35.943	12.400	17.322
OIL & GREASE	0.800	12.000	3.152	0.800	2.864	0.800	2.790	0.100	0.662
TOTAL ORG CARBON	2.400	17.000	5.466	2.400	5.091	2.400	4.994	2.800	3.259
NH3 & ORG N	0.500	2.600	0.941	0.500	0.887	0.500	0.873	0.400	0.499
NITRATE	0.130	4.000	0.943	0.130	0.843	0.130	0.818	0.160	0.297
TOTAL P	0.100	0.130	0.106	0.100	0.106	0.100	0.105	0.100	0.101
SILICA	2.600	18.000	5.834	2.600	5.438	2.600	5.336	2.800	3.330
SULFATE	2.800	240.000	52.612	2.800	46.518	2.800	44.943	3.200	11.928
CHLORIDE	1.000	7.000	2.260	1.000	2.106	1.000	2.066	1.000	1.223
CALCIUM	2.200	100.000	22.738	2.200	20.225	2.200	19.576	2.800	6.308
ARSENIC	0.005	0.014	0.007	0.005	0.007	0.005	0.007	0.005	0.005
CADMIUM	0.002	0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.002
COPPER	0.003	0.010	0.004	0.003	0.004	0.003	0.004	0.003	0.003
IRON	0.055	0.700	0.190	0.055	0.174	0.055	0.170	0.068	0.089
LEAD	0.010	0.020	0.012	0.010	0.012	0.010	0.012	0.010	0.010
MANGANESE	0.007	0.490	0.108	0.007	0.096	0.007	0.093	0.005	0.023
MOLYBDENUM	0.020	1.100	0.247	0.020	0.219	0.020	0.212	0.020	0.060
ZINC	0.008	0.028	0.012	0.008	0.012	0.008	0.012	0.006	0.007
SUSPENDED SOLIDS	1.000	91.475	20.000	1.000	17.675	1.000	17.075	1.300	4.598

SCENARIO #4 - HILL CREEK AT 55 YEARS
LOW FLOW
FLOW RATES IN MILLIONS OF GPD

	NATURAL RUNOFF	+	DISTURBED RUNOFF	=	003 OUTFALL	+	NATURAL RUNOFF	=	HILL CREEK AT FALLS	+	NATURAL RUNOFF	=	HILL CREEK AT CONFLUENCE	+	NATURAL RUNOFF	=	KETA CONFLUENCE
RATE	2.504		0.666		3.170		0.440		3.610		0.140		3.750		22.968		26.718
DISSOLVED OXYGEN	11.900		7.000		10.871		11.900		10.996		11.900		11.030		11.600		11.520
TOTAL DISS SOLIDS	11.900		500.000		114.401		11.900		101.908		11.900		98.547		19.600		30.681
HARDNESS	6.300		200.000		46.977		6.300		42.019		6.300		40.686		8.200		12.760
ALKALINITY	11.300		150.000		40.427		11.300		36.877		11.300		35.922		12.400		15.701
OIL & GREASE	0.800		12.000		3.152		0.800		2.865		0.800		2.788		0.100		0.477
TOTAL ORG CARBON	2.400		17.000		5.466		2.400		5.092		2.400		4.992		2.800		3.108
NH3 & ORG N	0.500		2.600		0.941		0.500		0.887		0.500		0.873		0.400		0.466
NITRATE	0.130		4.000		0.943		0.130		0.844		0.130		0.817		0.160		0.252
TOTAL P	0.100		0.130		0.106		0.100		0.106		0.100		0.105		0.100		0.101
SILICA	2.600		18.000		5.834		2.600		5.440		2.600		5.334		2.800		3.156
SULFATE	2.800		240.000		52.612		2.800		46.541		2.800		44.908		3.200		9.054
CHLORIDE	1.000		7.000		2.260		1.000		2.106		1.000		2.065		1.000		1.149
CALCIUM	2.200		100.000		22.738		2.200		20.235		2.200		19.561		2.800		5.153
ARSENIC	0.005		0.014		0.007		0.005		0.007		0.005		0.007		0.005		0.005
CADMIUM	0.002		0.004		0.002		0.002		0.002		0.002		0.002		0.002		0.002
COPPER	0.003		0.010		0.004		0.003		0.004		0.003		0.004		0.003		0.003
IRON	0.055		0.700		0.190		0.055		0.174		0.055		0.170		0.068		0.082
LEAD	0.010		0.020		0.012		0.010		0.012		0.010		0.012		0.010		0.010
MANGANESE	0.007		0.490		0.108		0.007		0.096		0.007		0.093		0.005		0.017
MOLYBDENUM	0.020		1.100		0.247		0.020		0.219		0.020		0.212		0.020		0.047
ZINC	0.008		0.028		0.012		0.008		0.012		0.008		0.012		0.006		0.007
SUSPENDED SOLIDS	1.000		91.475		20.000		1.000		17.684		1.000		17.061		1.300		3.512

TABLE III-8

SUMMARY OF MODELING RESULTS FOR COMPLIANCE
WITH PROPOSED ADEC RECEIVING WATER QUALITY STANDARDS[1/]

Parameter	Standard[2/]	Outfall 001				Outfall 003			
		Scenario No. 1		Scenario No. 2		Scenario No. 3		Scenario No. 4	
		avg.	low	avg.	low	avg.	low	avg.	low
Dissolved Oxygen	>7	X[3/]	X	X	X	X	X	X	X
Total Dissolved Solids	<500	X	X	X	X	X	X	X	X
Alkalinity	>20	X	X	X	X	X	X	X	X
Nitrate	<10	X	X	X	X	X	X	X	X
Sulfate	<200	X	X	2,000[4/]	2,000	X	X	X	X
Chloride	<200	X	X	X	X	X	X	X	X
Arsenic	<0.19 C	X	X	X	X	X	X	X	X
Cadmium	<0.0039 A	X	X	X	X	X	X	X	X
Copper	<0.011 C	X	X	X	X	X	X	X	X
Iron	<1.00 C	X	X	X	X	X	X	X	X
Lead	<0.82 A	X	X	X	X	X	X	X	X
Manganese	<0.1	13,000	14,000	62,000	67,000	15,000	15,000	4,000	4,000
Zinc	<0.047 C	X	X	X	X	X	X	X	X
Suspended Solids	<20	X	X	X	X	X	X	X	X

1/ Based upon existing standards at time of modeling (1984). Acute values were used based upon discussions with ADEC and/or data deficiencies as noted in text.

2/ Value is proposed ADEC standard used in model (1984). Where applicable, A denotes acute value, C denotes chronic value. All units in mg/l.

3/ X indicates outfall water satisfied proposed 1984 ADEC standards.

4/ Numerical value indicates approximate feet downstream of discharge where contaminant is diluted to meet proposed 1984 ADEC standard.

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TABLE III-9

COMPARISON OF DISTURBED AREA CHARACTERIZATION TO
APPLICABLE FEDERAL AND STATE WATER QUALITY STANDARDS

	Parameters (mg/l or as noted)	Disturbed Area Characterization	NSPS Effluent Limitations 1/	ADEC Receiving Water Quality Standards 2/	State Drinking Water Standards
1	pH, units	7.00	6.0 - 9.0	6.5 - 9.0	-
2	Total Dissolved Solids	500.00	-	3/	1,000
3	Hardness (as $CaCO_3$)	200.00	-	-	-
4	Alkalinity (as $CaCO_3$)	150.00	-	>20.0	-
5	Oil and Grease	12.00	-	-	-
6	Total Organic Carbon	17.00	-	-	-
7	NH_3 and Org Nitrogen (as N)	2.60	-	-	-
8	Nitrate Nitrogen (as N)	4.00	-	<10.0	45
9	Total Phosphorus (as P)	0.13	-	-	-
10	Silica (as SiO_2)	18.00	-	-	-
11	Sulfate (as SO_4)	240.00	-	<200.0	500
12	Chloride	7.00	-	<200.0	500
13	Calcium	100.00	-	-	-
14	Suspended Solids	4/	30.0/20.0	5/	-
15	Dissolved Oxygen	7.00	-	>7.0	-
16	Arsenic 6/	0.014	-	0.360/0.190	0.05
17	Cadmium	0.004	0.10/0.05	0.0039/0.0011	0.010
18	Chromium (hexavalent)	-	-	0.016/0.011	0.05
19	Copper	0.010	0.30/0.15	0.018/0.012	1.0
20	Iron	0.700	-	-/1.00	0.03
21	Lead	0.020	0.6/0.3	0.082/0.0032	0.05
22	Manganese	0.490	-	-/-	0.05
23	Mercury	-	0.002/0.001	0.0024/0.000012	0.002
24	Molybdenum	1.100	-	-/-	-
25	Nickel	-	-	1.4/0.16	-
26	Selenium	-	-	0.26/0.035	0.01
27	Silver	-	-	0.0041/0.00012	0.05
28	Zinc	0.028	1.5/0.75	0.12/0.11	5.0

1/ See Appendix E, Table IIA.
2/ See Appendix E, Section IIB and Table II-3.
3/ Increase in TDS shall not exceed one-third of the concentration of the natural condition of the body of water.
4/ Suspended solids concentration was back-calculated for each mass balance scenario so that the discharge would be 20 mg/l.
5/ Standard is no measurable increase above background. Assumed to be 30/20 mg/l for calculation purposes.
6/ Trace metal concentrations for disturbed area characterization is dissolved portion only, for NSPS effluent limitations the concentrations represent total metals and for ADEC standards the concentrations are based on total recoverable metals. See discussion in Appendix E, Section III-F, for explanation of how these different concentrations were found to be comparable in this analysis.

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- In scenario No. 2 a mixing zone approximately 2,000 feet downstream of the Beaver Creek outfall would be required for sulfate. This mixing zone boundary corresponds with the location of the Lower Beaver Creek Falls.

- In all cases, the total dissolved solids concentrations comply with the Class 1A(i) standard of 500 mg/l but not with the stricter Class 1A(iii) standard. In scenarios No. 1 and No. 2 for Beaver Creek where the natural TDS concentration is 22 mg/l, a one-third increase allows for the addition of another 7.3 mg/l, or a maximum concentration of 29.3 mg/l. The mass balance TDS concentrations after various degrees of dilution range from 452 mg/l to 138 mg/l, which are 20 to 6 times the natural level. In scenario No. 3, the stricter standard is exceeded under natural conditions because when White Creek, which has a TDS of 35 mg/l, flows into Hill Creek with a TDS of 11.9 mg/l, the resulting concentration represents a two-fold increase over Hill Creek background. For scenarios No. 3 and No. 4, the mass balance concentrations exceed the stricter standard by 24 to 6 times.

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IV. DECANT WATER QUALITY FOR ON-LAND TAILINGS DISPOSAL

Three on-land tailings alternatives are presented with one tailings pond in the Tunnel Creek drainage basin and another in Aronitz Creek. The following tailings pond description details and assumptions were considered in evaluating the effects of on-land tailings disposal on water quality:

1. The tailings slurry will be discharged along the slopes of the impounded basin and the upstream face of the dams to deposit a 25-ft thick layer of tailings that will provide a relatively impermeable membrane. This design consideration would minimize seepage into the groundwater and through the dam. Therefore, impacts to the groundwater from the dissolved constituents in the liquid phase of the tailings effluent (residual milling reagents, trace metals, etc.) should be minimal.

2. The Aronitz Creek spillway decant structure will direct all discharged water directly into Boca de Quadra, thus bypassing the remaining portion of the creek drainage basin below the dam. Therefore, the discharge would not impact the surface water of this drainage basin.

3. The Tunnel Creek spillway decant structure will direct all discharged water into the natural creek channel below the dam, about 50-100 ft upstream from the mouth of Tunnel Creek.

4. The liquid phase of the tailings effluent as presented in Appendix A, Table II-5 complies with BAT criteria for the selected trace metals. See Table 4-7 for comparisons. Therefore, only if the trace metals concentrations increased due to recycling would the discharge exceed NPDES limitations.

In order to evaluate the effects of recycling on the trace metal concentrations in the Tunnel Creek tailings pond, the following mass balance with simplifying assumptions was performed for one trace metal, copper. All other metal concentrations would behave similarly in a mass balance of recycling.

- There will be no evaporation from the pond that would contribute to the concentrating of dissolved constituents.

- Seepage from the pond would be minimal because the tailings will form a relatively impermeable layer.

- The 20 percent - 30 percent of the water in the tailings slurry that would remain trapped within voids in the tailings solid will not be considered to simplify calculations.

- Every time the water is recycled through the milling process, the same concentration of copper (0.035 mg/l) will be added to the effluent regardless of the incoming concentration of copper. In actual milling operations, high incoming concentrations of a trace metal could affect the efficiency of the chemical reactions used to separate the desired molybdenum.

- The change in concentration of copper, which in reality is a continuous process, will be calculated for specific time steps in order to utilize the iterative capacity of the computer.

Equations for Mass Balance:

$$\frac{d\ \text{conc(in pond)}}{dt} = \frac{\text{mass(in pond)} + \text{mass(added from effluent)} - \text{mass (wt)}}{\text{volume (of pond)}}$$

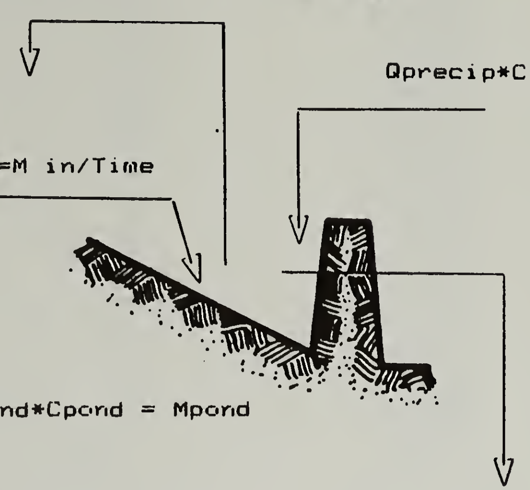
$$\text{Pct. conc(in pond)} = \frac{\text{mass(pond)/time} + \text{mass(added)/time} - \text{mass(wt)/time}}{\text{volume (of pond)}}$$

The diagram and equations for recycling in the Tunnel Creek tailings pond are presented below.

Results:

Using 1 hour time steps for the iterative process, the concentration of copper, in this case, in the pond reaches a steady state value of 0.0231 mg/l after about 90 hours. This pond concentration would remain approximately the same as long as inflow from precipitation runoff is continuously diluting the effluent mass loading.

CONCENTRATIONS IN TUNNEL CREEK TAILINGS POND WITH RECYCLE
ON-LAND TAILINGS DISPOSAL



Cpond = Crecycle = Cdischarge

Cin(initial) = 0.035 mg/l

Cin(at time I) = Cin(initial)+Cpond(at time I-1)

Cprecip = 0.003 mg/l (Tunnel Creek Baseline)

Cpond(initial) = Cprecip

Vpond = 3,000 ACRE-Feet = 3.7*10**6 liters

Qin = Qrecycle = 16,600 gpm = 3.77*10**6 liters/hour

Qdischarge = Qprecip =106 cfs= 10.8*10**6 liters/hour

Qout = Qin + Qprecip = Qrecycle + Qdischarge

Min = Mass added in time step I

Min = (Qin(I)*Cin*time) + (Qprecip*Cprecip*time)

Mout = Mass lost from pond in time step I

Mout = Qout*Cpond(I-1)*time

Mpond = Mass in pond at time I

Mpond = Cpond(I-1)*Vpond

Delta_C = change in concentration during time step I

Delta_C = (Min+Mpond-Mdischarge)/Vpond

Cpond(I) = Cpond(I-1)+ Delta_c

EFFECT OF RECYCLING ON TUNNEL CREEK TAILINGS POND CONCENTRATIONS

TIME STEP IN HOURS IS 1   NUMBER OF DAYS SPECIFED IS 7

TIME STEP HRS	EFFLUENT CONC MG/L	POND CONC MG/L	TIME STEP HRS	EFFLUENT CONC MG/L	POND CONC MG/L
1	0.03500	0.00300	46	0.05766	0.02360
2	0.03800	0.04166	47	0.05860	0.02274
3	0.07666	0.00613	48	0.05774	0.02353
4	0.04113	0.03878	49	0.05853	0.02280
5	0.07378	0.00878	50	0.05780	0.02347
6	0.04378	0.03635	51	0.05847	0.02285
7	0.07135	0.01102	52	0.05785	0.02342
8	0.04602	0.03430	53	0.05842	0.02290
9	0.06930	0.01290	54	0.05790	0.02338
10	0.04790	0.03256	55	0.05838	0.02294
11	0.06756	0.01450	56	0.05794	0.02334
12	0.04950	0.03110	57	0.05834	0.02297
13	0.06610	0.01584	58	0.05797	0.02331
14	0.05084	0.02986	59	0.05831	0.02300
15	0.06486	0.01698	60	0.05800	0.02329
16	0.05198	0.02882	61	0.05829	0.02302
17	0.06382	0.01794	62	0.05802	0.02326
18	0.05294	0.02793	63	0.05826	0.02304
19	0.06293	0.01875	64	0.05804	0.02325
20	0.05375	0.02719	65	0.05825	0.02306
21	0.06219	0.01943	66	0.05806	0.02323
22	0.05443	0.02656	67	0.05823	0.02307
23	0.06156	0.02001	68	0.05807	0.02322
24	0.05501	0.02603	69	0.05822	0.02308
25	0.06103	0.02050	70	0.05808	0.02321
26	0.05550	0.02558	71	0.05821	0.02309
27	0.06058	0.02091	72	0.05809	0.02320
28	0.05591	0.02520	73	0.05820	0.02310
29	0.06020	0.02126	74	0.05810	0.02319
30	0.05626	0.02488	75	0.05819	0.02311
31	0.05988	0.02155	76	0.05811	0.02318
32	0.05655	0.02461	77	0.05818	0.02312
33	0.05961	0.02180	78	0.05812	0.02318
34	0.05680	0.02438	79	0.05818	0.02312
35	0.05938	0.02201	80	0.05812	0.02317
36	0.05701	0.02419	81	0.05817	0.02312
37	0.05919	0.02219	82	0.05812	0.02317
38	0.05719	0.02403	83	0.05817	0.02313
39	0.05903	0.02234	84	0.05813	0.02317
40	0.05734	0.02389	85	0.05817	0.02313
41	0.05889	0.02246	86	0.05813	0.02316
42	0.05746	0.02378	87	0.05816	0.02313
43	0.05878	0.02257	88	0.05813	0.02316
44	0.05757	0.02368	89	0.05816	0.02314
45	0.05868	0.02266	90	0.05814	0.02316

V. EXISTING GROUNDWATER QUALITY CHARACTERIZATION

Existing groundwater quality characterization and a summary of water quality characteristics of deep groundwater samples are provided in Tables V-1 and V-2, respectively.

TABLE V-1

EXISTING GROUNDWATER QUALITY CHARACTERIZATION 1/

Parameter 2,3/	Bakewell Lake Area EW-1			Lower Tunnel Creek EW-3			Fuel Cache EW-5			Raspberry Creek EW-7		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temperature, °C	5.0	9.5	7.9	5.9	8.1	6.9	3.0	10.0	6.2	2.0	5.3	4.0
Dissolved Oxygen	0.1	7.1	3.1	2.3	3.8	3.0	1.3	7.1	3.9	1.9	6.8	3.6
pH (field), units	5.9	6.4	6.2	5.2	6.2	5.7	6.7	7.8	7.3	6.1	7.4	6.6
Color, pcu	100	750	425	50	300	112	10	20	15	<2	20	15
Specific Conductance, µmhos/cm	80.0	170.0	114.3	46.0	80.0	61.0	420.0	550.0	510.0	134.0	330.0	212.8
Total Dissolved Solids	73.0	150.0	96.5	45.0	135.0	79.3	300.0	380.0	329.2	94.0	180.0	129.0
Total Hardness (as $CaCO_3$)	39.0	52.0	44.5	14.0	32.0	23.5	260.0	290.0	275.0	81.0	150.0	101.7
Total Alkalinity	50.0	72.0	57.8	21.0	33.0	27.8	210.0	270.0	256.7	79.0	150.0	101.7
Total Organic Carbon	1.3	8.6	4.9	5.2	34.0	12.9	1.6	7.6	4.5	0.2	6.7	2.7
Sodium	3.00	5.00	4.15	1.10	4.00	2.10	3.30	11.00	6.65	1.10	2.50	1.45
Nitrate Nitrogen (as N)	0.020	0.420	0.180	<0.020	0.750	-	<0.020	0.180	-	<0.020	0.070	-
Fluoride	<0.100	0.200	0.125	<0.100	0.100	-	0.200	0.400	0.283	<0.100	0.300	0.160
Gross Alpha, pCi/l	<1.00	<1.30	-	<0.70	5.00	2.77	<2.00	<4.10	-	<0.90	<2.00	-
Chromium	<0.002	0.009	0.005	<0.002	0.003	-	<0.002	<0.002	-	<0.002	<0.002	-
Sulfate (as SO_4)	1.2	9.0	3.9	1.0	4.0	2.6	11.0	24.0	16.8	2.5	6.8	4.7
Chloride	<1.0	1.0	- 4/	<1.0	1.0	1.0	<1.0	<1.0	-	<1.0	1.0	-
Barium	<0.02	<0.02	-	<0.02	<0.02	-	<0.02	0.05	0.04	0.03	0.17	0.09
Arsenic	<0.005	0.033	0.026	<0.005	0.032	0.020	<0.005	0.022	-	<0.005	0.017	-
Cadmium	<0.002	<0.002	-	<0.002	0.002	-	<0.002	0.004	-	<0.002	0.004	-
Copper	<0.002	0.006	0.004	<0.002	0.004	0.003	<0.002	0.007	0.005	<0.002	0.003	0.002
Iron	1.500	35.000	19.530	1.400	7.600	5.400	0.010	0.280	0.148	0.150	0.450	0.263
Lead	<0.010	0.040	-	<0.010	<0.010	-	<0.010	0.020	-	<0.010	<0.010	-
Manganese	0.065	0.350	0.263	0.110	0.360	0.163	0.190	2.400	1.067	0.130	1.000	0.352
Zinc	0.009	0.110	0.033	0.017	0.120	0.045	0.016	0.310	0.112	0.003	0.120	0.046
Mercury	<0.0002	<0.0010	-	0.0003	<0.0010	0.0004	0.0004	0.0011	0.0006	<0.0002	<0.0010	0.0005
Selenium	<0.005	<0.005	-	<0.005	<0.005	-	<0.005	0.012	-	<0.005	<0.005	-
Silver	<0.002	<0.002	-	<0.002	<0.002	-	<0.002	<0.002	-	<0.002	<0.002	-

1/ Source: Golder Associates 1983b, Appendices C and D (Sampling period October, 1981 through October, 1983).
2/ All units are mg/l as element unless otherwise noted.
3/ All trace metals are dissolved portion only.
4/ Less than 20 percent of the samples are above lower level of detection, so no mean value was calculated.

TABLE V-1 (Continued)

EXISTING GROUNDWATER QUALITY CHARACTERIZATION 1/

Parameter 2,3/	Lower Beaver Creek EW-9			Middle Beaver Creek EW-10			Upper Beaver Creek EW-11			Lower Hill Creek EW-12		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temperature, °C	4.9	12.2	6.6	3.9	8.8	6.7	4.0	7.5	5.5	4.0	12.6	7.1
Dissolved Oxygen	1.5	3.9	2.5	1.7	3.5	2.6	1.0	1.9	1.4	1.5	4.4	2.6
pH (field), units	5.9	6.7	6.2	6.0	7.1	6.6	5.8	7.0	6.5	6.1	7.5	6.9
Color, pcu	<2	20	17	10	600	197	30	250	157	5	40	19
Specific Conductance, μmhos/cm	62.0	190.0	116.4	41.0	84.0	62.2	260.0	430.0	355.0	180.0	430.0	2[illegible]0.8
Total Dissolved Solids	47.0	120.0	72.5	17.0	64.0	38.0	140.0	360.0	227.5	140.0	290.0	1[illegible]8.3
Total Hardness (as $CaCO_3$)	18.0	86.0	39.5	9.0	38.0	21.3	140.0	195.0	175.8	85.0	120.0	109.2
Total Alkalinity	17.0	85.0	35.0	8.0	17.0	12.8	130.0	160.0	153.0	72.0	89.0	81.2
Total Organic Carbon	0.8	4.6	2.2	1.6	6.5	4.7	2.4	11.0	5.7	0.6	9.9	3.1
Sodium	0.10	6.00	2.70	<0.10	2.00	1.24	1.00	17.00	5.27	4.30	14.00	7.53
Nitrate Nitrogen (as N)	<0.020	0.070	- 4/	<0.020	0.870	-	<0.020	0.140	0.075	<0.020	0.160	-
Fluoride	<0.100	0.300	0.167	<0.100	0.200	0.133	0.300	0.600	0.383	1.400	3.600	2.117
Gross Alpha, pCi/l	<0.40	<2.00	-	<0.20	<2.00	-	<1.70	<3.10	-	<1.20	4.60	2.34
Chromium	<0.002	<0.002	-	<0.002	0.003	-	<0.002	0.003	0.003	<0.002	0.003	-
Sulfate (as SO_4)	6.0	17.0	10.0	3.5	18.0	9.0	33.0	55.0	44.0	13.0	78.0	[illegible]7.0
Chloride	<1.0	1.0	1.0	<1.0	2.0	1.5	<1.0	<1.0	-	<1.0	1.0	1.0
Barium	<0.02	0.11	0.05	<0.02	0.04	-	0.06	0.22	0.12	<0.02	0.09	0.05
Arsenic	<0.005	0.014	0.011	<0.005	0.006	-	<0.005	0.023	0.014	<0.005	0.018	-
Cadmium	<0.002	0.028	-	<0.002	<0.002	-	<0.002	<0.002	-	<0.002	<0.002	-
Copper	<0.002	0.009	0.006	<0.002	0.005	0.004	<0.002	0.007	0.005	<0.002	0.006	0.004
Iron	0.220	1.500	0.685	1.500	12.000	6.700	1.400	8.700	5.950	0.150	3.200	1.105
Lead	<0.010	<0.010	-	<0.010	<0.010	-	<0.010	<0.010	-	<0.010	<0.010	-
Manganese	0.051	0.570	0.275	0.056	0.170	0.105	0.240	1.600	0.888	0.110	0.630	0.323
Zinc	0.042	0.120	0.087	<0.002	0.120	0.048	<0.002	0.046	0.020	<0.002	0.041	0.024
Mercury	<0.0002	0.0030	0.0011	<0.0002	<0.0010	0.0004	<0.0002	<0.0010	0.0005	<0.0002	0.0020	0.0008
Selenium	<0.005	<0.005	-	<0.005	<0.005	-	<0.005	<0.005	-	<0.005	0.0120	-
Silver	<0.002	<0.002	-	<0.002	<0.002	-	<0.002	<0.002	-	<0.002	<0.002	-

1/ Source: Golder Associates 1983b, Appendices C and D (Sampling period October, 1981 through October, 1983).
2/ All units are mg/l as element unless otherwise noted.
3/ All trace metals are dissolved portion only.
4/ Less than 20 percent of the samples are above lower level of detection, so no mean value was calculated.

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TABLE V-1 (Continued)

EXISTING GROUNDWATER QUALITY CHARACTERIZATION 1/

Parameter 2,3/	White Creek EW-13			Middle Hill Creek EW-14			Bear Meadow Core Hole 77-10 (30 ft)			Bear Meadow Core Hole 77-10 (190 ft)			Bear Meadow Adit 77-29		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temperature, °C	3.0	7.0	5.2	4.2	8.5	5.7	2.5	11.0	6.3	3.0	8.5	5.1	5.5	9.0	7.6
Dissolved Oxygen	1.6	2.8	2.3	3.3	6.6	5.2	1.2	4.3	2.6	0.9	4.1	2.7	1.3	2.7	2.1
pH(field), units	5.8	7.7	6.9	6.1	7.0	6.6	6.2	7.9	7.1	6.5	8.9	7.5	5.9	7.4	6.9
Color, pcu	<2	20	13	5	30	18	<2	20	11	<5	100	35	<2	10	-
Specific Conductance, µmhos/cm	1100.0	1400.0	1280.0	50.0	170.0	102.2	200.0	300.0	261.7	200.0	290.0	237.8	400.0	590.0	477.2
Total Dissolved Solids	1000.0	1200.0	1116.7	22.0	66.0	47.5	140.0	220.0	166.7	120.0	250.0	155.8	280.0	390.0	331.7
Total Hardness(as $CaCO_3$)	730.0	860.0	800.0	14.0	44.0	31.7	118.0	130.0	123.0	84.0	120.0	108.0	220.0	300.0	245.0
Total Alkalinity	102.0	130.0	112.0	12.0	28.0	20.3	92.0	100.0	98.5	71.0	100.0	92.3	110.0	140.0	125.0
Total Organic Carbon	1.2	4.2	1.8	1.5	17.0	6.3	1.0	6.9	2.7	0.6	5.6	3.0	0.4	24.0	7.0
Sodium	6.10	21.00	10.25	<0.10	2.40	1.44	0.70	5.30	2.58	0.40	6.10	3.72	6.50	13.50	10.43
Nitrate Nitrogen(as N)	<0.020	0.140	- 4/	0.020	0.070	0.047	<0.020	0.250	0.098	<0.020	0.370	0.107	<0.020	0.520	0.187
Fluoride	1.300	2.800	1.750	0.100	1.000	0.300	0.900	1.700	1.067	0.600	1.900	1.117	1.200	2.300	1.500
Gross Alpha, pCi/l	<2.00	57.00	42.73	<0.40	<2.00	0.70	<2.00	25.10	20.43	21.00	26.50	24.00	11.00	39.80	27.43
Chromium	<0.002	0.006	0.005	<0.002	0.005	0.004	<0.002	0.002	-	<0.002	0.003	0.003	<0.002	0.002	-
Sulfate(as SO_4)	550.0	750.0	645.8	<1.0	16.0	10.4	20.0	35.0	26.3	15.0	36.0	24.8	110.0	160.0	124.2
Chloride	<1.0	2.0	1.3	<1.0	2.0	1.5	<1.0	2.0	1.5	<1.0	2.0	1.5	<1.0	1.0	-
Barium	<0.02	0.20	0.12	<0.02	0.91	-	<0.02	0.15	-	<0.02	0.06	-	<0.02	0.08	0.05
Arsenic	<0.005	0.021	0.015	<0.005	0.014	-	<0.005	0.023	-	<0.005	0.019	0.013	<0.005	0.019	0.016
Cadmium	<0.002	0.003	-	<0.002	<0.002	-	<0.002	<0.002	-	<0.002	<0.002	-	<0.002	0.002	-
Copper	<0.002	0.015	0.008	<0.002	0.006	0.004	<0.002	0.010	0.007	<0.002	0.015	0.009	<0.002	0.026	0.013
Iron	0.020	0.380	0.167	0.200	0.650	0.355	0.060	0.240	0.165	0.260	0.950	0.528	0.070	0.350	0.195
Lead	<0.010	0.013	-	<0.010	<0.010	-	<0.010	<0.010	-	<0.010	<0.010	-	<0.010	0.060	-
Manganese	0.060	0.910	0.370	0.010	0.094	0.040	0.130	1.200	0.638	0.098	0.750	0.293	0.086	0.700	0.277
Zinc	<0.002	0.130	0.072	0.003	0.240	0.012	0.005	0.310	0.089	0.011	0.084	0.036	<0.002	0.280	0.101
Mercury	<0.0002	<0.0010	0.0005	<0.0002	<0.0010	0.0003	<0.0002	<0.0010	-	<0.0002	<0.0010	-	<0.0002	<0.0010	0.0004
Selenium	<0.005	0.028	0.023	<0.005	0.005	-	<0.005	0.005	-	<0.005	<0.005	-	<0.005	0.014	-
Silver	<0.002	0.005	-	<0.002	<0.002	-	<0.002	0.002	0.002	<0.002	<0.002	-	<0.002	<0.002	-

1/ Source: Golder Associates 1983b, Appendices C and D (Sampling period October, 1981 through October, 1983).
2/ All units are mg/l as element unless otherwise noted.
3/ All trace metals are dissolved portion only.
4/ Less than 20 percent of the samples are above lower level of detection, so no mean value was calculated.

TABLE V-2

SUMMARY WATER QUALITY CHARACTERISTICS OF DEEP GROUNDWATER SAMPLES 1/

	Bear Meadow Core Hole 77-10		White Creek Core Hole 80-139			
Parameter 2,3/	(170 - 224) 4/	(900 - 954)	(152 - 205)	(352 - 405)	(552 - 605)	(802 - 855)
Temperature, °C	8.0	6.4	9.0	8.5	9.0	9.0
Dissolved Oxygen	10.2	3.5	4.0	3.2	4.2	3.2
pH (lab), units	7.4	7.1	7.2	7.3	7.1	7.3
Color, pcu	10	30	100	50	20	<2
Specific Conductance, umhos/cm	350.0	290.0	1200.0	1000.0	1400.0	1500.0
Total Dissolved Solids	140.0	160.0	940.0	810.0	1300.0	130.0
Total Hardness (as $CaCo_3$)	120.0	130.0	680.0	600.0	900.0	850.0
Total Alkalinity	100.0	92.0	150.0	180.0	160.0	140.0
Total Organic Carbon	27.0	11.0	4.2	1.1	1.3	3.4
Sodium	2.6	2.5	9.0	7.0	10.0	20.0
Nitrate Nitrogen (as N)	0.73	<0.05	<0.05	0.05	0.05	<0.05
Fluoride	0.7	0.7	1.1	1.1	1.3	1.2
Gross Alpha, pCi/l	-	-	-	-	-	-
Chromium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Sulfate (as SO_4)	35.0	45.0	500.0	375.0	700.0	750.0
Chloride	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Barium	<0.02	<0.02	0.02	0.03	0.03	0.02
Arsenic	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium	<0.002	0.002	<0.002	<0.002	0.003	<0.002
Copper	0.003	0.003	0.009	0.008	0.011	0.011
Iron	0.58	2.60	1.20	1.40	1.80	3.80
Lead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	0.160	<0.002	<0.002	<0.002	0.130	<0.002
Zinc	0.250	0.170	0.049	0.080	0.092	0.180
Mercury	0.0005	<0.0002	0.0002	0.0002	0.0002	0.0004
Selenium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

1/ Source: Golder Associates 1983b, Tables C-12, C-14, C-15, C-16, C-17, and C-18 (samples obtained in August, 1983).
2/ All units are mg/l as element unless otherwise noted.
3/ All trace metals are dissolved portion only.
4/ Sample interval (depth in feet).

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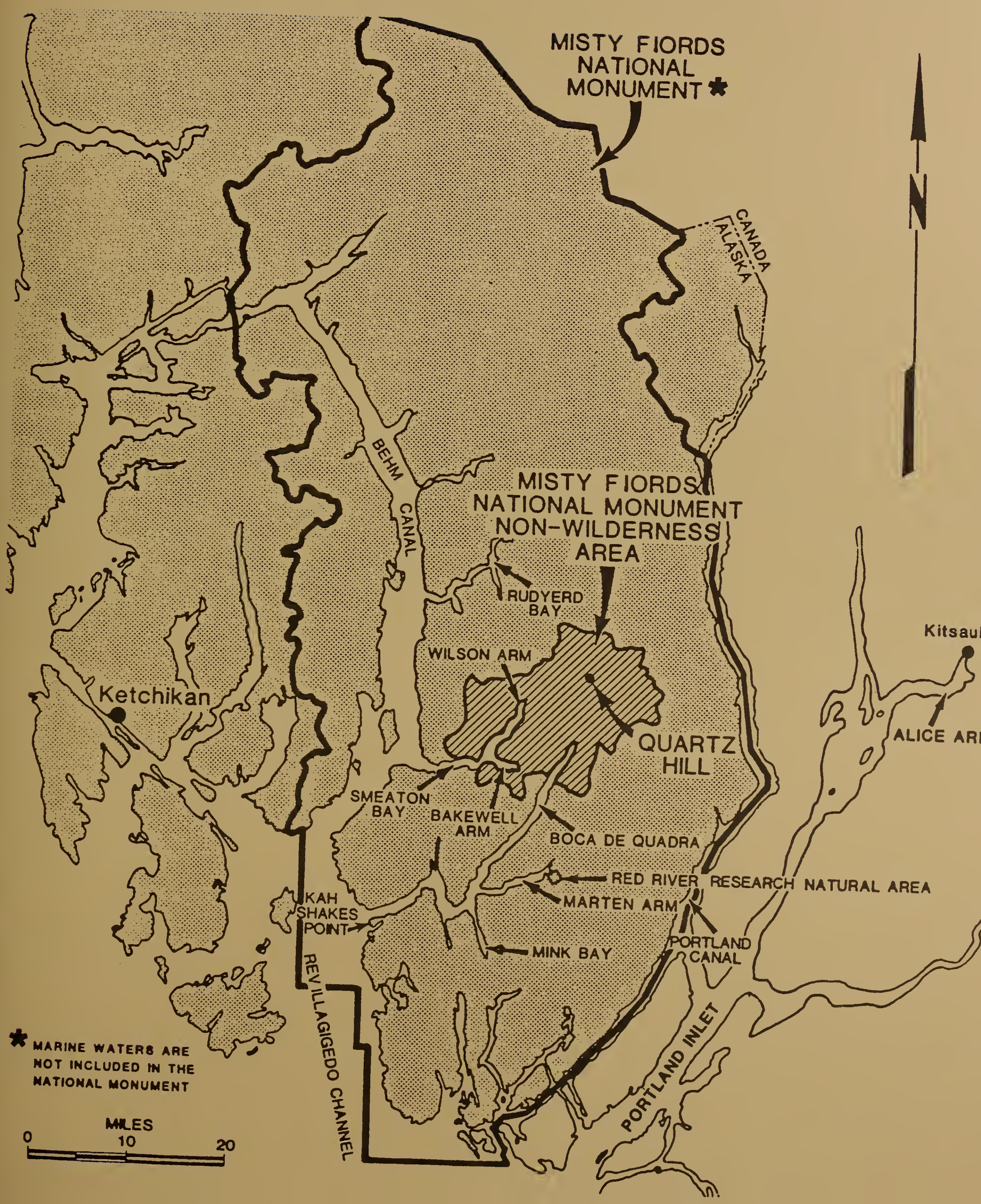
APPENDIX F
OCEANOGRAPHY



APPENDIX F

OCEANOGRAPHY

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INTRODUCTION

The Quartz Hill project relates to proposed mining activities at a site 45 miles east of Ketchikan, in southeast Alaska (Figure F-1). Molybdenum ore, extracted by open pit mining, would be processed on-site to produce a concentrate for shipping. Large quantities of tailings result from this mode of operation, and, as described elsewhere, submarine disposal is the most feasible disposal alternative.

Two nearby fjords were given the most extensive consideration for the disposal of tailings--Boca de Quadra and Wilson Arm/Smeaton Bay. Boca de Quadra, to the south of the mine, is a long and narrow fjord with multiple sills and side arms, connecting with the Revillagigedo Channel. To the southwest of the mine lies Wilson Arm/Smeaton Bay, a smaller fjord with two sills and a single side arm (Bakewell Arm). In this case, connection to the Revillagigedo Channel (and thence Dixon Entrance) is via Behm Canal. Details of the fjords, including vertical sections along the central axes are shown in Figure F-2.

Tailings disposal has been carried out at the Island Copper site in Rupert Inlet on Vancouver Island since 1971, and much data of relevance to the Quartz Hill project have been acquired there. The geographic setting of Rupert Inlet is shown in Figure F-3, together with contours of tailings disposition after 6 years of disposal.

The purpose of this appendix is to summarize the physical and chemical oceanographic processes that together determine the expected impact of tailings disposal in either fjord. The first section, Physical Oceanography, includes a description of the modeling approaches that have been employed to predict the behavior of tailings. The second section, Chemical Oceanography, presents information concerning the chemical makeup of the tailings and the chemical changes that may take place following disposal in seawater.

PHYSICAL OCEANOGRAPHY

The physical oceanography of Boca de Quadra and Wilson Arm/Smeaton Bay has been extensively studied through field programs conducted by the Institute of Marine Science of the University of Alaska, Fairbanks (Nebert 1984, 1985). The results of these studies are discussed elsewhere in this document (Section 3.1.6 and Appendix S). Several excellent reference texts are also available (e.g., Freeland et al. 1980; Ellis 1982) that provide a wealth of information of relevance to this project.

Before describing specific models that have been implemented to investigate the process of sedimentation and tailings dispersal within these fjords, a summary of their physical oceanography may be useful. While precipitation in the drainage basins of Boca de Quadra and Smeaton Bay is high, river runoff is at most a few percent of the tidal prism, defined as fjord surface area times tidal range. Perhaps as a result, the fjords have "reverse estuarine" circulation patterns. Normal estuarine circulation has surface outflow of brackish water and

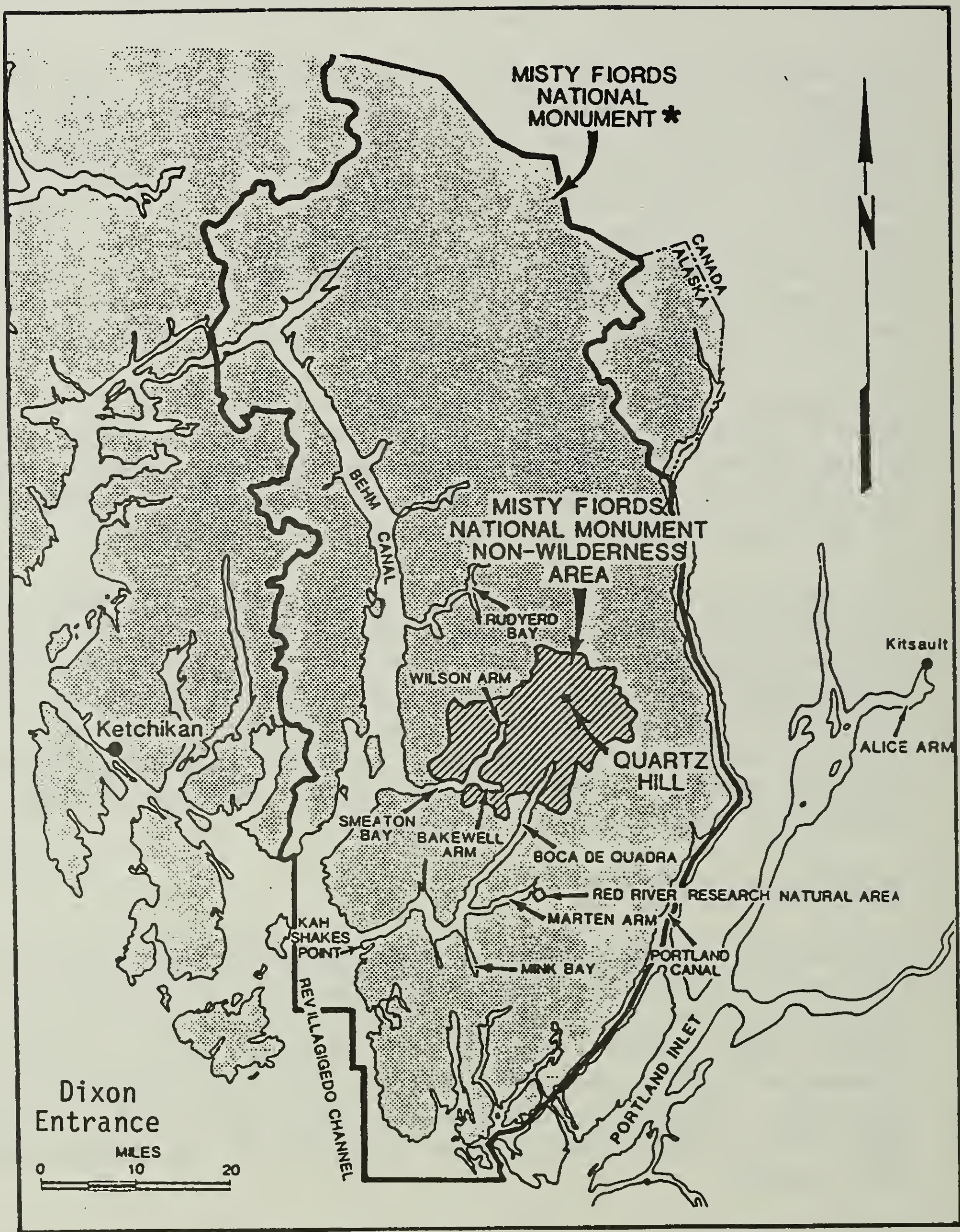
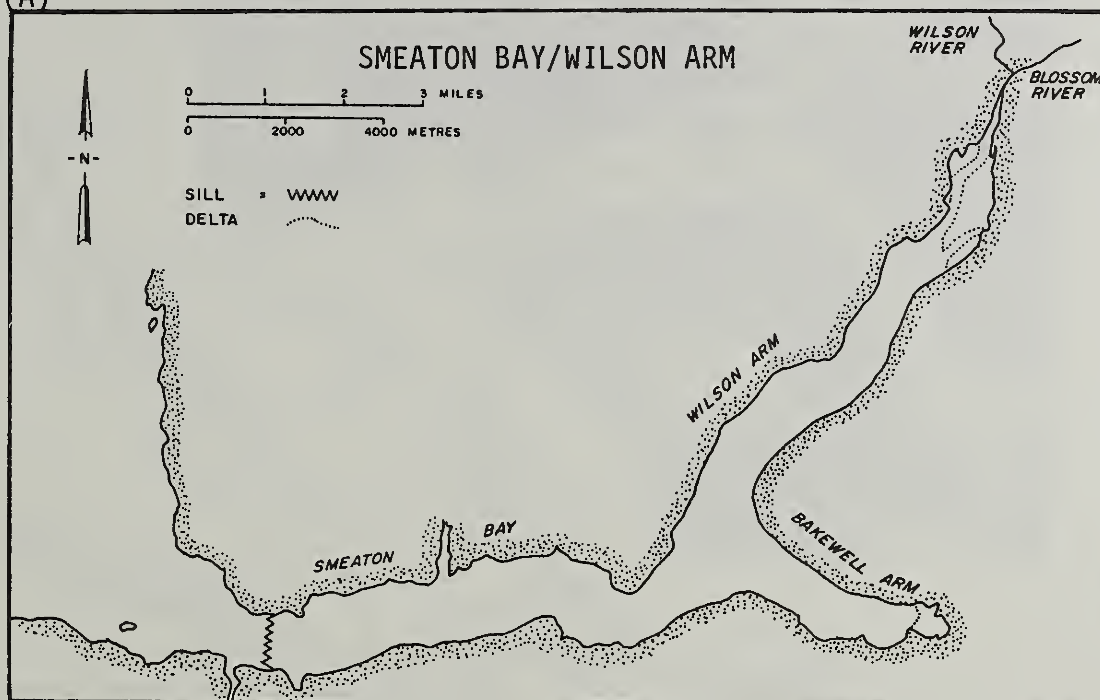


FIGURE F-1

LOCATION OF THE QUARTZ HILL
MOLYBDENUM SITE IN SOUTHEAST ALASKA

(A)



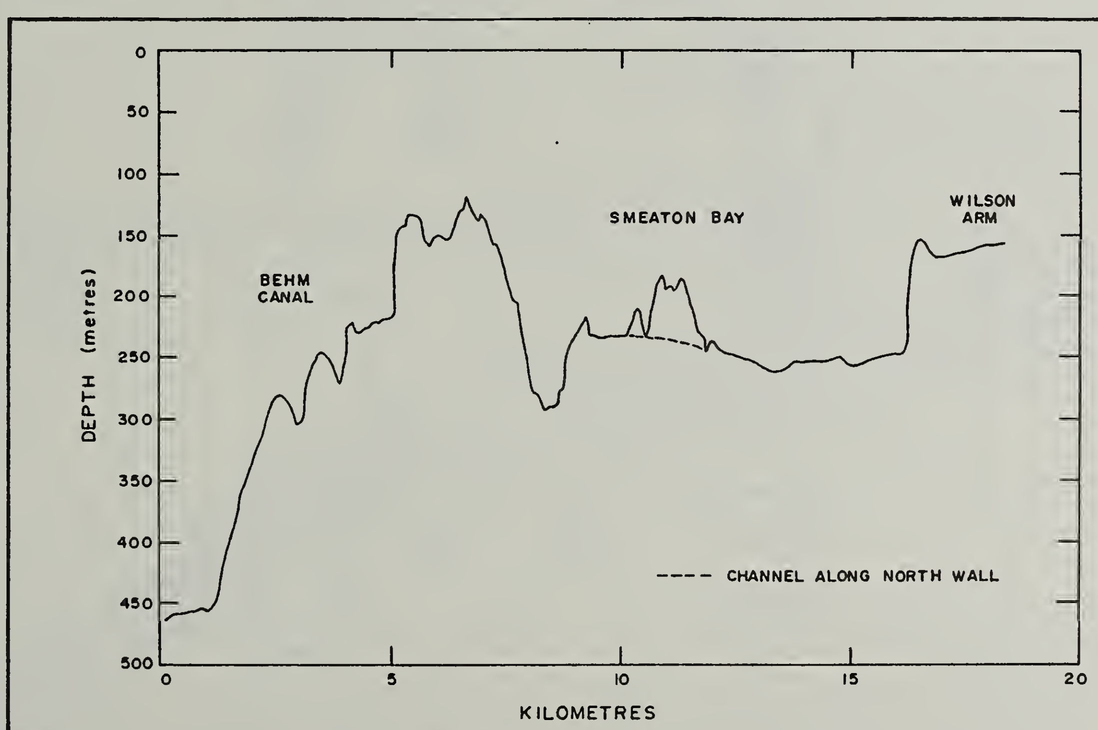


FIGURE F-2

GEOGRAPHIC FEATURES AND AXIAL BATHYMETRY FOR
(A) WILSON ARM/SMEATON BAY AND
(B) BOCA DE QUADRA FJORD SYSTEMS
Adapted from Rescan (1984) and Burrell (1983)

(B)

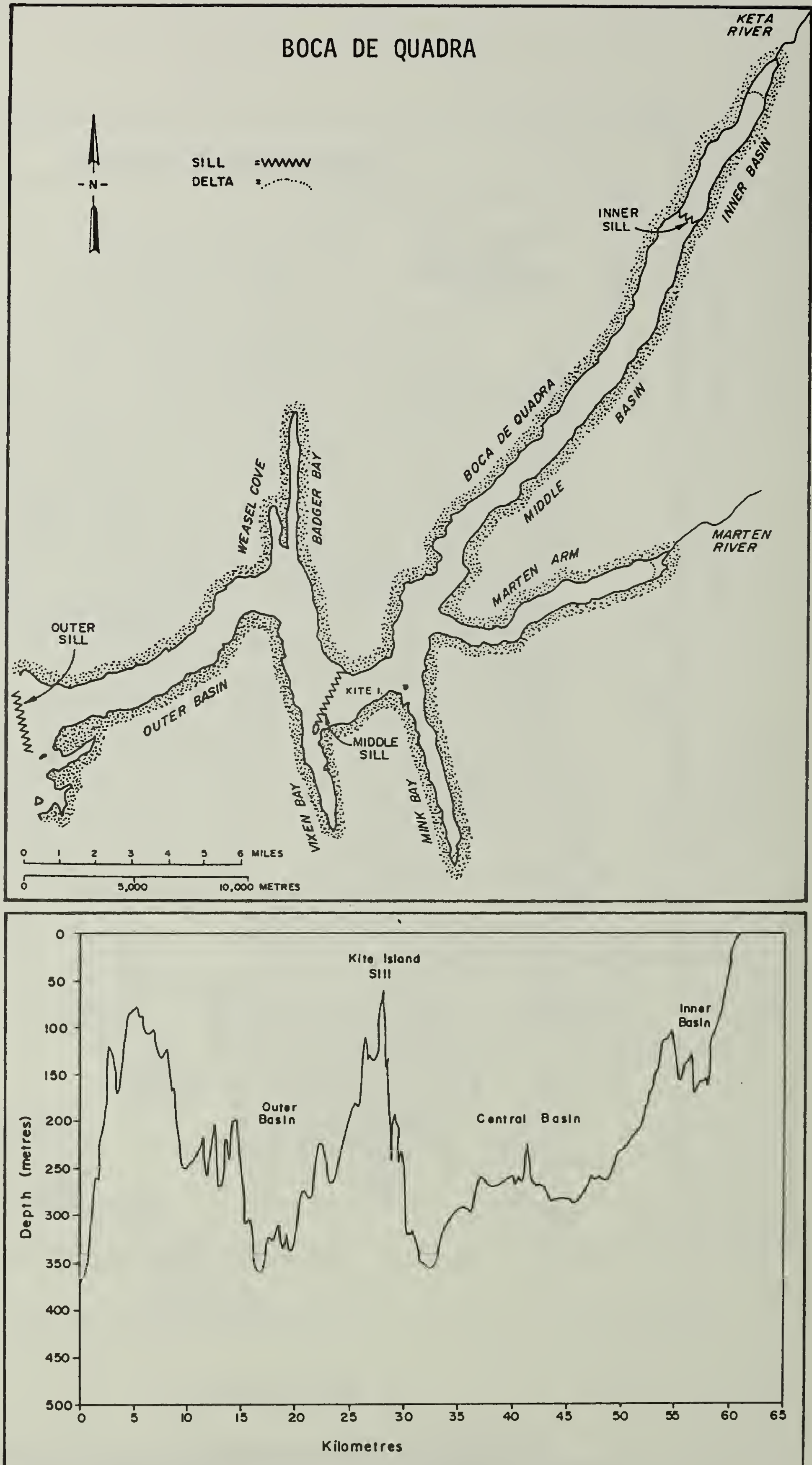


FIGURE F-2 (CONTINUED)

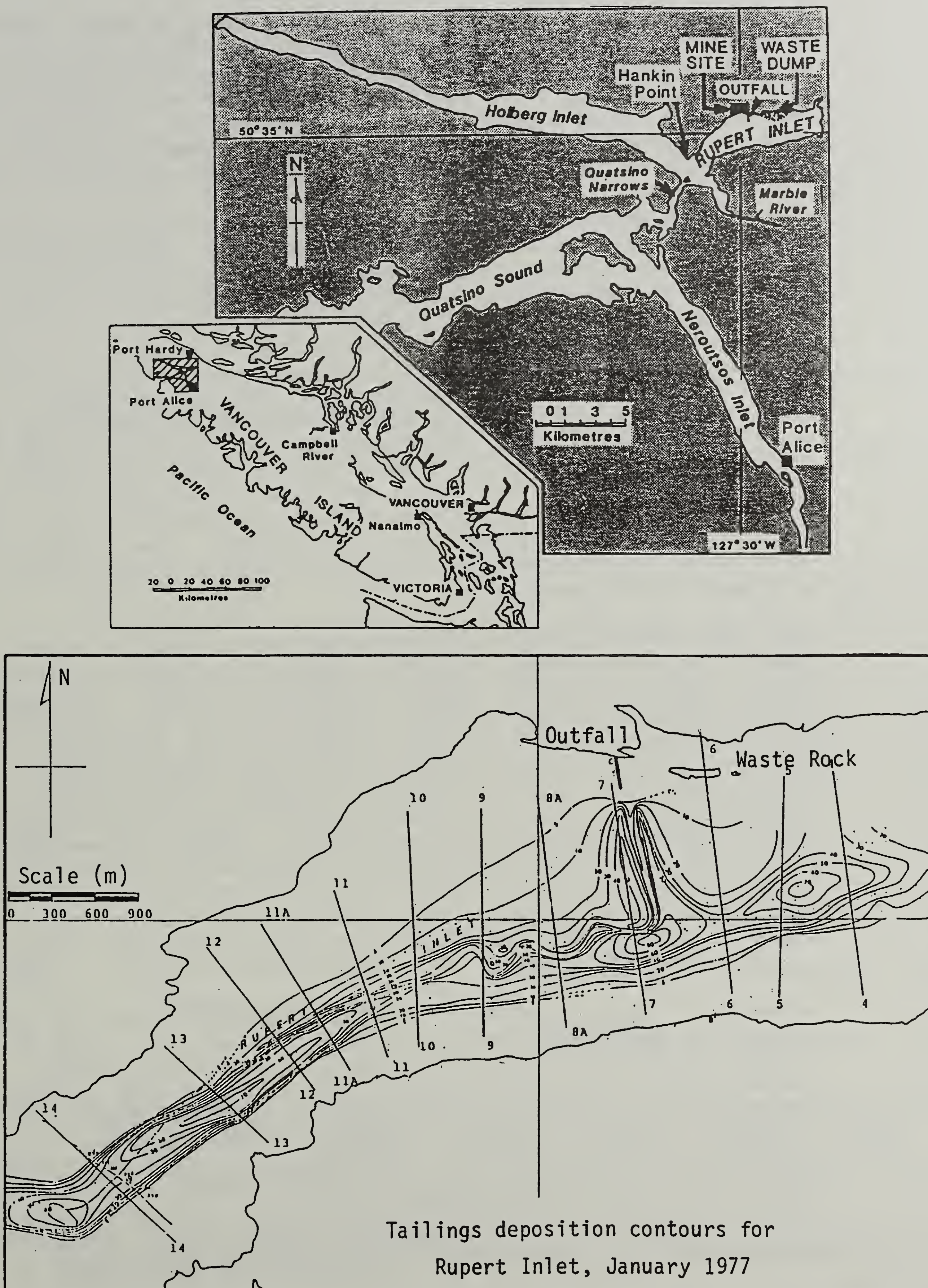


FIGURE F-3
GEOGRAPHIC FEATURES OF THE ISLAND COPPER MINE SITE IN RUPERT INLET, WITH TAILINGS DEPOSITION AS OF JANUARY 1977
Adapted from Ryan (1983)

a compensating inflow of denser, more saline water at depth. Nebert (1982, 1985) shows the reverse is typically the case at the outer sills of Boca de Quadra and Smeaton Bay. With the possible exception of the poorly sampled upper 10 m, surface waters tend to move inward, while between 80 m and sill depth there is a mean outflow. He suggests that vertical mixing within these fjords may lead to greater water densities through much of the upper water column than exists outside the fjords.

The dominant wind patterns in the southeast Alaska region for much of the year are associated with coastal downwelling. Surface wind drift is onshore, and the underlying denser water is displaced offshore. Together with high regional precipitation, this leads to a rather low density coastal water mass. In summer and fall, downwelling relaxes, and some weak upwelling may occur. This is seen in Figure F-4, where a multiyear record of monthly upwelling index and its 20-year average annual cycle are drawn for Dixon Entrance. The index is based on gradients of the wind field, derived from surface pressure maps, as described by Bakun (1973). The relaxation of downwelling brings denser water to sill depth. When sill depth density exceeds the density within the fjord below sill depth, deep water renewal can occur. On the flood tide, denser water flows into the fjord and sinks to the bottom (or to a level appropriate to its density). The process of deep water renewal can proceed, even though the tidally averaged flow at sill depth may be seaward.

Deep water renewal occurs as a density current over sills in the fjord. The driving force is gravity acting on the density difference between the incoming water and the ambient fjord water. The density current (negatively buoyant plume) is dissipated by entrainment of overlying water and by frictional resistance at the fjord bed. The injection of mine tailings gives rise to another density current flowing downfjord. Here, the negative buoyancy is supplied by the suspended tailings load, and the density difference is degraded by particle settling as well as by entrainment. Notice that whereas strong dilution is a desirable feature in many outfall situations, this is not the case for mine tailings disposal. Rather a coherent flow that carries the suspended tailings material to the deeper regions of the fjord and minimizes the dispersal of fines in the upper water column is the aim.

Schematic circulation patterns for Wilson Arm/Smeaton Bay, during the renewal and nonrenewal periods, are shown in Figure F-5. In both periods, the vertical circulation should serve to keep suspended sediments from rising into the upper water column and the euphotic layer. This is a positive feature in relation to the fate of tailings fines. On the other hand, the net outflow at sill depth may facilitate the transport of tailings out of these fjords. The mixing at depth, required to maintain the circulation described above, acts to reduce stratification and distribute fines vertically. An energy source for this mixing may lie in tidally generated internal waves, and plunging hydraulic jets, as described by Farmer (1982) for Knight Inlet in

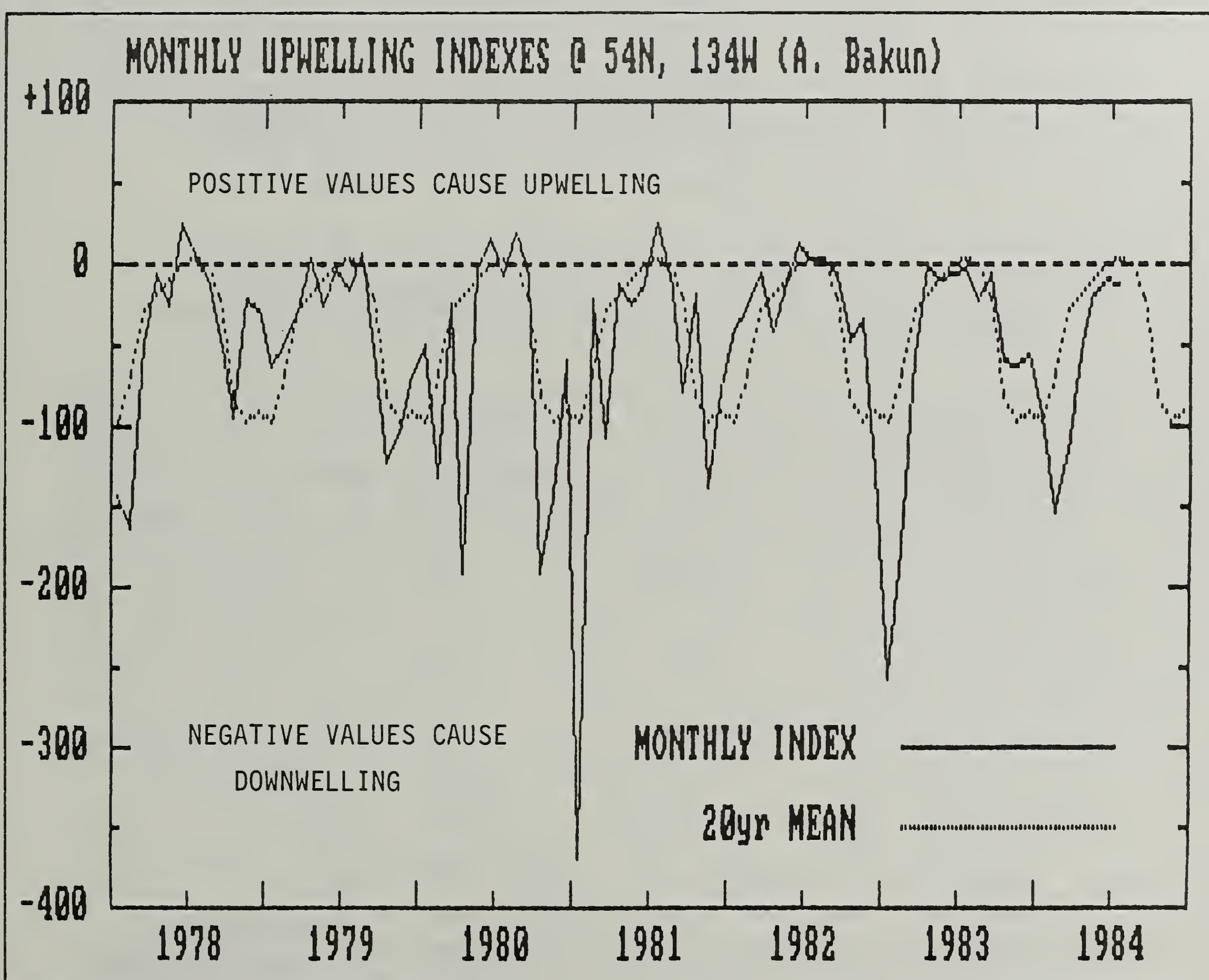


FIGURE F-4

MONTHLY UPWELLINGS AND 20-YEAR MEAN ANNUAL CYCLE NEAR DIXON ENTRANCE
Adapted from Nebert (1985)

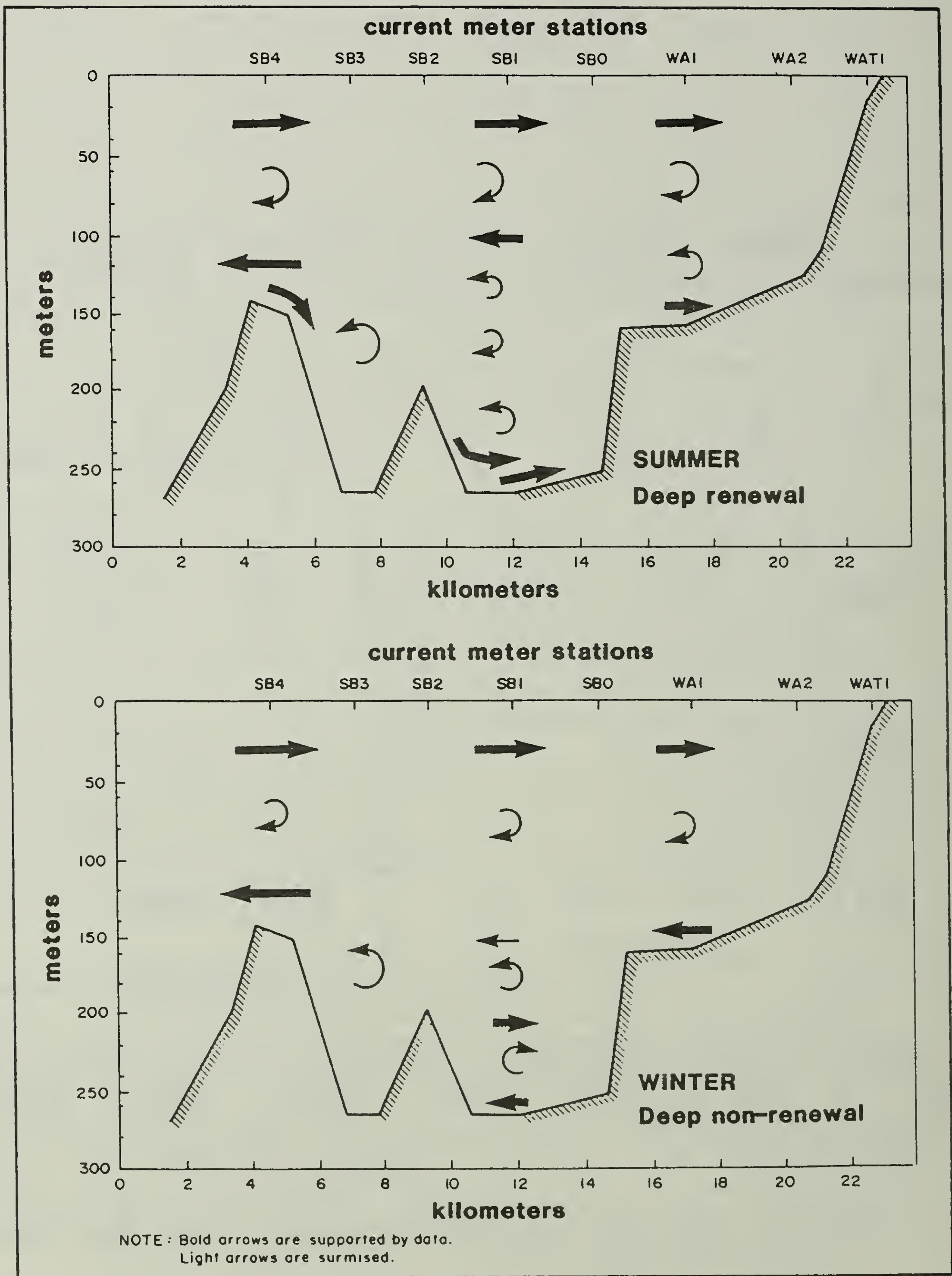


FIGURE F-5
SCHEMATIC CIRCULATION FOR WILSON ARM/SMEATON BAY
FOR THE SUMMER DEEP RENEWAL AND WINTER NONRENEWAL SEASONS
Adapted from Nebert (1985)

British Columbia. Farmer (1982) suggests that such features could be incorporated in mathematical models of circulation. He cautions, however, that the output of a model is only as good as the physics it contains.

Submarine dispersal of tailings in a fjord involves a multitude of processes, operating on different space and time scales. Rather than attempt a single model, including all aspects of the interaction of the negatively buoyant tailings plume with the circulating fjord waters, the overall modeling task has been partitioned into three stages:

- A Near-Field physical model (Jain and Kennedy 1984) has been constructed to investigate the immediate vicinity of the outfall. Extending 100 m downslope from the outfall, the near field is a region where the behavior of the tailings plume is believed to depend strongly on outfall design.

- A Density Current/Sedimentation model (Findikakis 1983) has been used to predict the far-field behavior of tailings. This region begins at the edge of the near field, and extends over the remainder of the fjord system.

- Fjord Circulation models have been implemented to predict the dispersal of suspended tailings material throughout the water column. Time-dependent (Kowalik 1984) and steady-state (EPA 1988) treatments have been employed as discussed below.

In the first two phases of modeling the circulation of the overlying waters of the fjord is ignored. The overlying water column plays a passive role, merely as a source for entrainment and dilution of the density current. In the final stage, changes in the fjord bed form due to sedimentation are ignored. The circulation models are aimed at predicting the distribution of tailings material in response to the hydrodynamics of the fjord. A time-dependent, finite difference model has been implemented by Kowalik (1984). Here, the various physical processes are represented as explicit mathematical expressions, with definite numerical values for the parameters. Given that such models are typically expensive to run in terms of computer resources, they can sometimes be criticized for not fully exploring the range of possible parameter values. An alternate approach has been adopted by the U.S. Environmental Protection Agency (EPA 1988). A simpler steady state model is constructed, and run in a "Monte Carlo" mode. Probability distributions are chosen to reflect the ranges within which each parameter is believed to lie. Numerous model runs are performed, with a randomly selected set of parameter values for each. The model results from many runs were summarized statistically to represent the expected behavior and associated uncertainties of the system, and thereby assist the process of risk assessment.

THE NEAR FIELD

The near-field region is defined as extending 100 m from the tailings outfall. This choice reflects the conventional definition of 100 outfall diameters, with an outfall pipe diameter on the order of 1 m.

The tailings discharge will take place at a depth of 50 m, with the negatively buoyant plume flowing down the steep slope of the fjord. A literature search was performed by Bechtel (1983) to find appropriate mathematical models and suitable validation data for this situation. While some preliminary calculations were reported by Ryan (1983), suggesting that dilution of the tailings plume by factors of 15-80 takes place within the near field, it was felt that a suitably designed physical scale model could provide further insight into the complex dynamics near the outfall. This was done at the Institute of Hydraulic Research at the University of Iowa (Jain and Kennedy 1984).

To achieve a truly representative physical model, it is necessary to include the processes that dominate the real-world situation. Dimensionless numbers (independent of the system of units in use) are used to express the relative importance of various processes. For density currents (negatively buoyant plumes), such as the tailings discharge, the densimetric Froude number is of primary importance. It relates the flow velocity (V) to the density difference between the plume and the receiving waters ($\Delta\rho$), the receiving water density (ρ), the gravitational acceleration (g), and the characteristic length scale (L) of the process.

$$F = \sqrt{\frac{V}{(g\ L\ \Delta\rho/\rho)}} \tag{1}$$

Note that when L is taken as the plume thickness, the numerator represents the velocity of small waves on the upper surface of the plume. The Froude number, in this form, is related to the inverse square root of the bulk Richardson number, used in the sedimentation model of Findikakis (1983). A Froude number of 1 is the dividing line between subcritical ($F < 1$) and supercritical ($F > 1$) flows. Transition between supercritical and subcritical flow results in an hydraulic jump. The modeling of this process is discussed in the next section.

The physical model used was constructed at 1/50 the size of the prototype outfall. Tailings material from test borings at the Quartz Hill site and fresh water as the receiving fluid set the "reduced gravity" ($g\ \Delta\rho/\rho$) at close to its field value. Thus, in order for the model to have the same Froude number as the situation being modeled, it is necessary that the model velocity be reduced as the square root of the model scale. To maintain the aspect ratio of the tailings trajectories, it is necessary that their settling velocity (W_s) scale in the same manner. For the fine-sand and silt particle sizes appropriate to the tailings:

$$W_s = \frac{g\ \Delta\rho\ d^2}{(18\ \rho\ v)} \tag{2}$$

where d is the particle diameter, and v the kinematic viscosity. To achieve the correct modeling of trajectories, it is thus necessary that particle diameters be scaled down as the square root of the settling velocity, or the fourth root of the length scale reduction factor. The

tailings used in the model runs were screened to make their size distribution conform as well as possible with this requirement. The dimensionless Reynolds number

$$Re = VD/v, \tag{3}$$

where D is the diameter of the model outfall orifice, lies in the range 8,000-16,000, confirming that the model tailings jet is fully turbulent.

The physical model setup is shown in Figure F-6. A hinged sloping floor is attached to one end of a freshwater tank. Sediment is vigorously stirred in an adjacent mixing tank with a volume of fresh water to achieve the desired premixing (expressed as a ratio of tailings slurry to added water). The mixture is heated to achieve a density difference equivalent to that between the discharged fluid and the receiving fluid in the fjord. A pump discharges the mixture, at a constant rate, through an outlet pipe at floor level. An instrument carriage is positioned to extract water samples for the determination of sediment concentration and to monitor water temperature.

These latter measurements, combined with the initial temperatures in the mixing and model tanks, conveniently delineate the extent of the plume and provide an estimate of its dilution. Still and video imagery of the plume and bottom sediment buildup were collected, and after each run the tank was drained to allow measurements of the bottom sediment profile.

A total of 49 model runs were made to investigate the effects of

o	Bottom slope	(5°, 12.5°, 25°)
o	Premixing	(1:1, 1:2, 1:4)
o	Exit jet velocity	(1.1, 2.5, 4.5 m/s)
o	Outlet diameter	(0.95, 1.9 m)

on the tailings plume structure and dilution. The numbers in parentheses are the ranges of parameter values tested (expressed in full-scale terms where appropriate). The dominant influence was found to be bottom slope. The plume behavior is influenced by bottom deposits, and appears to be unsteady, with three distinct flow types possible:

- o Jet flow, with deposition in a fan widening downstream from the outlet;

- o Sheet flow, where a scoop or crater builds about the outlet with the sediment plume overflowing the edge, which acts an hydraulic control; and

- o Channel flow, where a widening and deepening channel is scoured by the flow through previously deposited sediment.

The dilution of the plume at 100 m was found to dependent on flow type, with typical values of 24-42 for jet flow, 9-16 for sheet flow, and 5-9 for channel flow. A dilution factor of 24 implies that only 1 part in

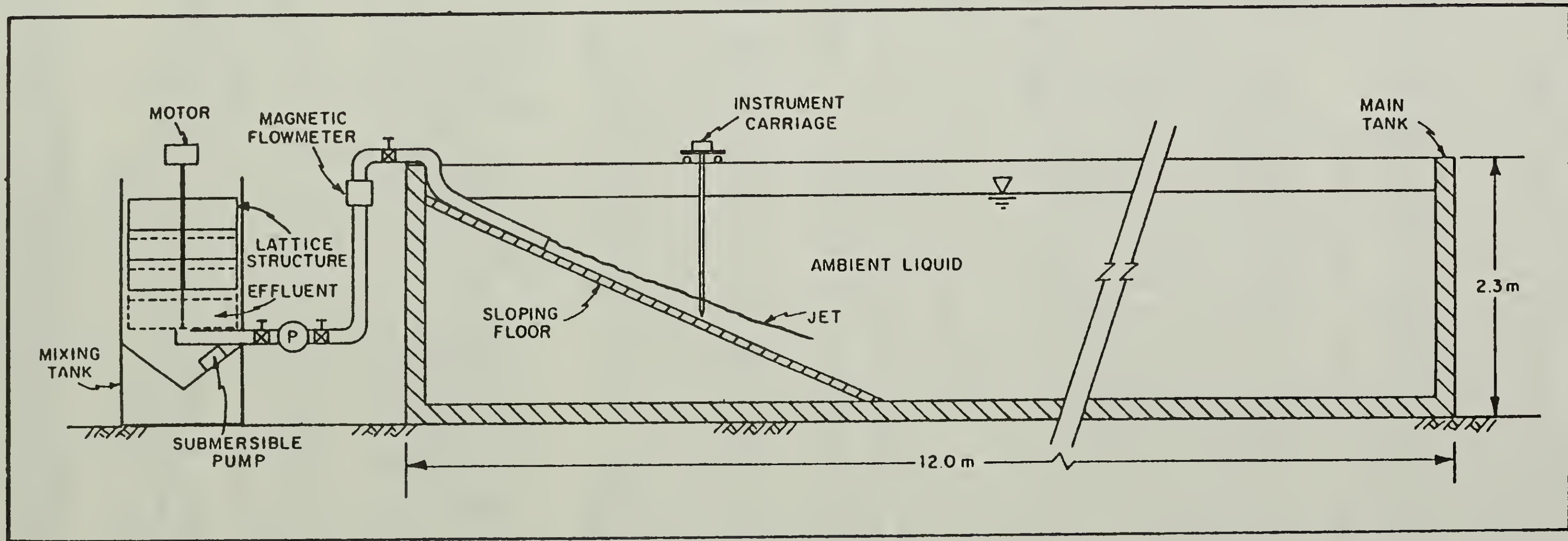


FIGURE F-6

SCHEMATIC DIAGRAM OF THE 1:50 SCALE MODEL OF NEAR-FIELD TAILINGS DISCHARGE
Adapted from Jain and Kennedy (1984)

24 by volume of the plume originates from the outlet. The remainder is entrained from the ambient fluid. The minimum dilution decreases with decreasing bottom slope. The jet flow dilutions are in reasonable agreement with the findings of the preliminary analytical modeling efforts of Bechtel (1983).

Among other model results, the following are of note:

- For small slopes, the sedimentation in the immediate vicinity of the outlet was enough, in several instances, to bury the outlet. Since the model scaling does not include the shear strength of tailings material, this does not indicate that similar burying would occur at full scale.

- Some runs were aimed at investigating whether a "split plume" forms when the plume falls freely from a raised outlet, before impinging on the bed. Such a split plume, if it occurred, might be an unwanted source of suspended fines in the upper water column, but none of the trials revealed such an occurrence once air bubbles in the discharge line were eliminated. The tailings plume was, in all cases, coherent and attached to the bottom in a thin layer 5 m thick in full-scale units.

- Although fresh water was used in the model, substitution of salt water in two runs produced no noticeable changes.

- In another test run, unscreened tailings were substituted for the screened sediments used to satisfy model scaling requirements. Apart from increased deposition of the coarse fraction in the vicinity of the outlet, the observed sheet flow field and dilution for the unscreened sediment was within the range found for screened sediment runs.

THE DENSITY CURRENT/SEDIMENTATION MODEL

On leaving the near-field region, the sediment plume flows as a density current along the floor of the fjord. A numerical model was produced (Findikakis 1983) to predict the dynamics and sediment deposition associated with this density current. The model is formulated as follows:

- The time history of sediment deposition is broken into a series of steps, longer than the periods of dominant tidal components;

- Flow variables are time-averaged within each interval;

- An estimated mean squared semidiurnal tidal velocity is added to the quadratic bottom stress term;

- The initial concentration of tailings in the sediment plume is chosen with reference to the dilutions predicted by the near-field model;

- The density current is confined within a trapezoidal channel, whose geometry is based on stream bed morphology and observations from Rupert Inlet;
- The tailings distribution is divided into several size classes; the behavior of each class is modeled separately, then the results composited to predict net deposition along the fjord;
- For each sediment size fraction, velocity and particle concentration are assumed to be uniformly distributed across the channel;
- The sediment distribution is checked for unstable slopes and, if necessary, redistributed by simulated slumps; and
- The resulting bed form is used as input to the next time step.

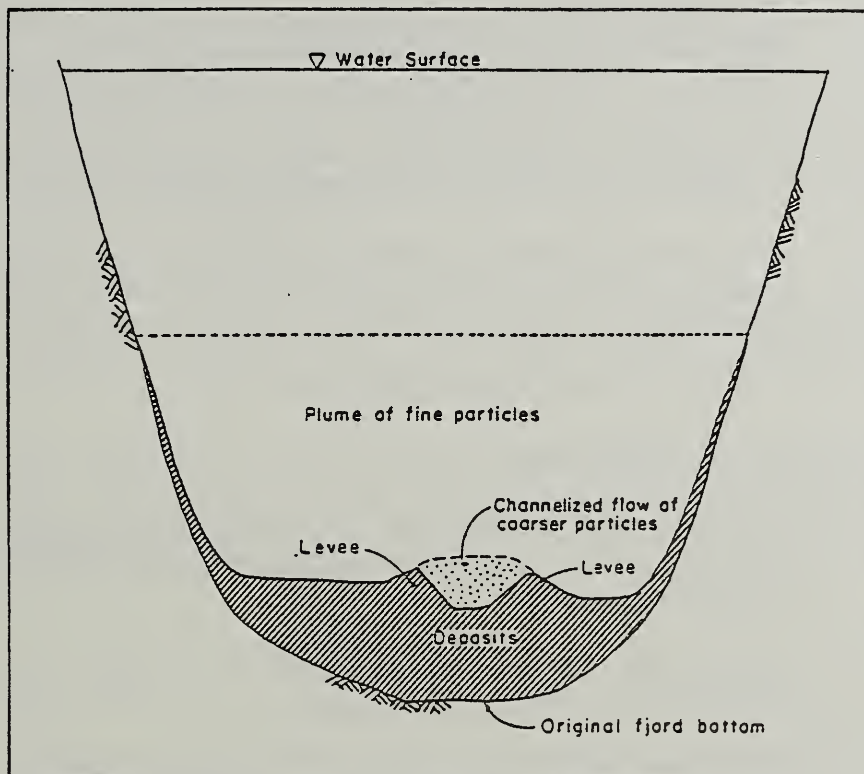
This scheme leads, for each time interval, to a set of first order ordinary differential equations with respect to distance along the channel. These linear equations are solved numerically using fourth order Runge-Kutta schemes. The model output is in the form of sediment distribution and movement within each size class and the modified bed profile at discrete times in the simulated life of the mine. The model may be run for each of the potential outfall locations. Several free parameters arise in the model. These are selected with reference to the literature, or from calibration runs aimed at replicating the sedimentation history at Island Copper/Rupert Inlet.

In Figure F-7, schematic sections in the across-fjord and along-fjord directions are drawn at a point in time following the initiation of tailings discharge. A density current of coarser sediment particles is confined to a channel between levees, while the finer particles are spread in a plume across the width of the fjord. The tailings deposition within Rupert Inlet, shown in contour in Figure F-3, support this picture. As is proposed for Quartz Hill tailings, the discharge is through a submerged outlet on the steep sidewall. Levees and the channel are clearly evident. The model confines <u>all</u> particles to the channel, which is assigned a trapezoidal section. Thus, the overlying plume of fine particles (see Figure F-7) is not represented by the model. Channel geometry varies along its length in response to the bottom slope and local flow characteristics, and dimensions are assigned based on surface stream morphology, with side slopes drawn from Island Copper observations.

Conservation equations, in the form of first order differential equations, are written at each time step, based on the sediment distribution resulting from the previous step.

Conservation of Volume:

- Changes in flux along the channel occur through entrainment of the overlying water.



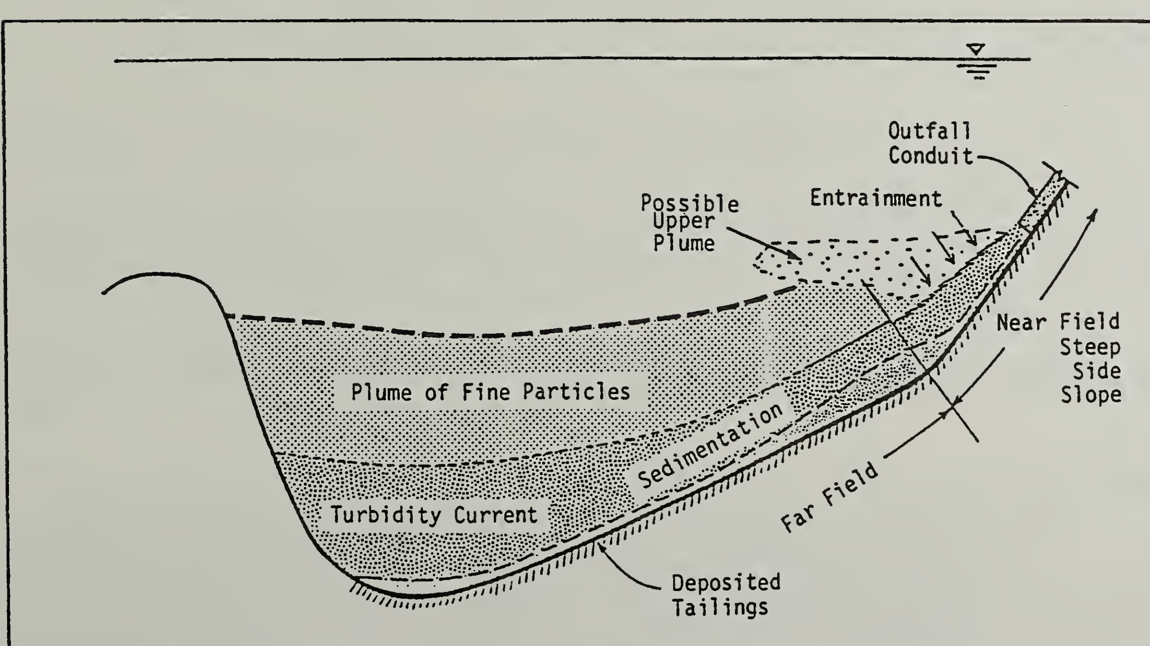


FIGURE F-7
SCHEMATIC CROSS-FJORD AND ALONG-FJORD SECTIONS OF TAILINGS DENSITY CURRENT AND THE SEDIMENTATION PROCESS
Adapted from Ryan (1983) and Findikakis (1983)

- Entrainment is assumed to depend on the velocity of the density current, with a constant of proportionality that is a function of the bulk Richardson number.

Conservation of Momentum:

- Momentum changes along the channel are in response to bottom and interfacial shear stresses, the pressure gradient along the channel, and the downslope gravity force.

- The bottom stress is written as a quadratic drag law, with the addition of the estimated mean square of the semidiurnal tidal current. The friction factor is based on Manning's n.

- The shear at the interface with the overlying water is set to a fraction (0.43) of the bottom stress.

- The pressure forces along the channel act through the center of area of the channel, as computed from the trapezoidal geometry.

- Diffusive fluxes are ignored.

Conservation of Total Mass:

- Density changes along the channel are in response to entrainment of overlying "ambient" water and sediment losses by deposition.

- The density of the ambient water is a specified function of the distance along the channel.

- The Stokes settling velocity of Equation (2) is modified by a factor reflecting "hindered settling" N

$$(1 - \sum_{i=1}^{N} \rho\, C_i/\rho_i)^5 \tag{4}$$

  Here C_i and ρ_i are the concentration by mass and density of the ith tailings size fraction, and N is the number of size classes.

- Fine cohesive particles form coagulants, whose settling velocity is expressed as

$$W_s = a_c\, C^{4/3} \tag{5}$$

  where C is the concentration of particles smaller than a critical diameter above which coagulation does not occur. This diameter and the constant a_c, are determined by laboratory experiment using tailings from the Quartz Hill site.

Conservation of Mass for each sediment size class:

- Changes in the concentration by mass C_i for each size class along the channel occur due to entrainment of ambient water and by particle deposition.

- A particle may deposit when the bottom shear stress falls below critical value. The probability (J_i) that a particle, in the ith size class, sticks to the bottom is given by

$$J_i = 1 - \tau_B / \tau_{cr_i} \tag{6}$$

  For bottom stresses exceeding the critical value, no deposition can occur. The critical stress value is obtained by modifying the empirical results for flows of solid-liquid mixtures in pipes.

- Note that the model does not appear to include scouring, though reference is made to Smith (1977), who suggests that sediment resuspension occurs when the bottom stress exceeds a critical stress value for erosion.

- An alternative criterion for deposition is that it will occur when the settling velocity exceeds the root mean square (rms) vertical component of the bottom turbulence. In this case, Equation (6) is replaced by

$$J_i = 1 - (u_* / a_d W_{s_i})^2 \tag{7}$$

  where u_* is the shear velocity, and a_d is a calibration parameter.

  Data from Rupert Inlet indicate that Equation (7) yields more realistic predictions.

The model incorporates a treatment of the "arrested current" that arises when the density current encounters an adverse gradient too high to surmount. When the current is arrested, all remaining suspended material is assumed to settle out. Internal hydraulic jumps are also incorporated in the model. The bottom slopes in fjords are relatively steep, and the density current may be supercritical. If the flow farther downfjord is subcritical, then a hydraulic jump will occur at, or near, where the steep slope ends. Arrested current and hydraulic jumps are illustrated schematically in Figure F-8.

Several important processes are associated with hydraulic jumps, such as enhanced entrainment and increased deposition, and these are included in the model. The computations necessary to locate a potential jump are rather complex. Given that the integration of the model equations proceeds in the downstream direction, the downfjord condition can only be estimated. Details of this procedure can be

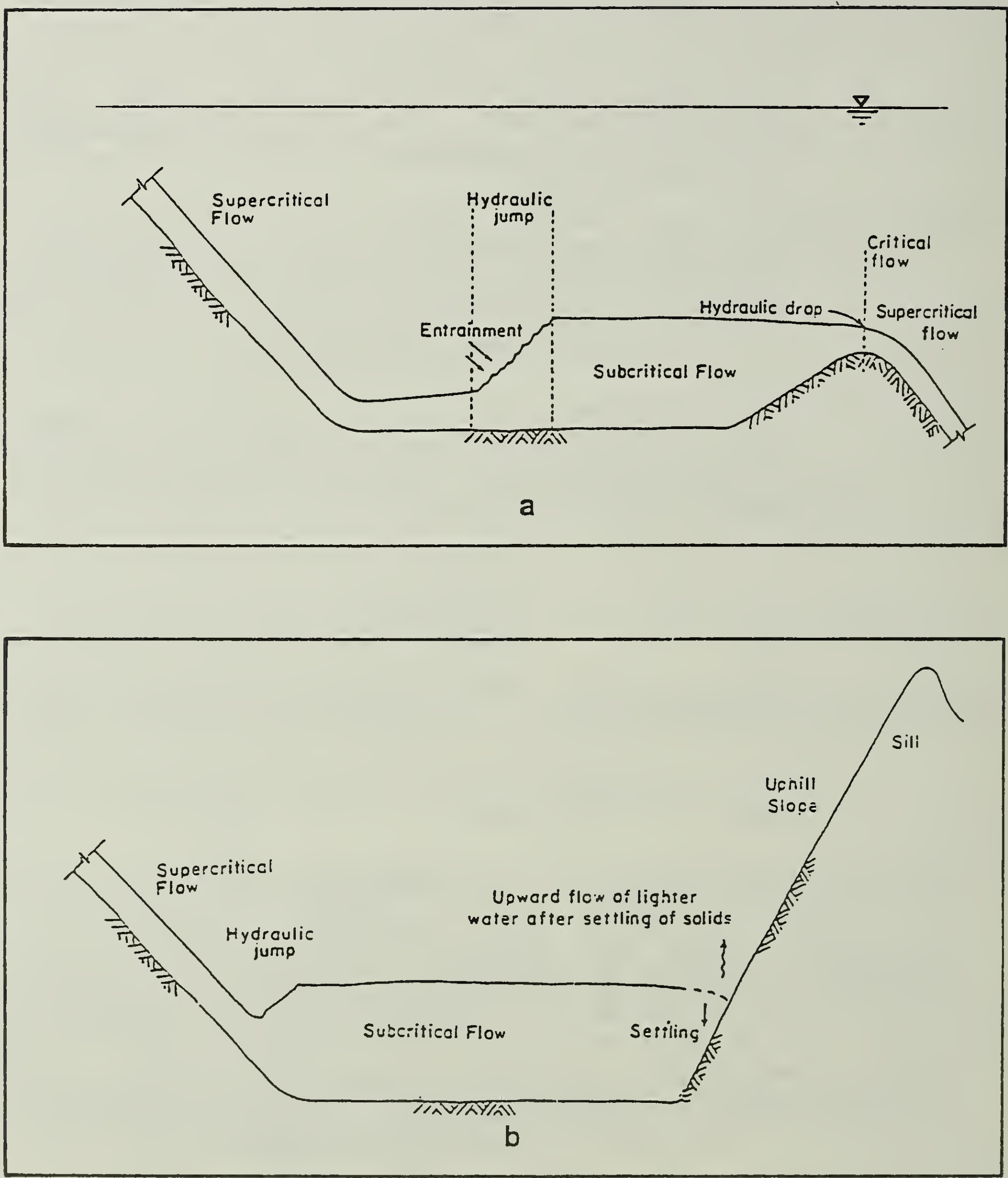


FIGURE F-8
DENSITY CURRENT BEHAVIOR ASSOCIATED WITH (A) A HYDRAULIC JUMP AND FLOW OVER A LOW SILL AND (B) THE ARRESTED CURRENT DUE TO A HIGH SILL
Adapted from Ryan (1983)

found in Findikakis (1983). Once the jump location is determined, a control volume surrounding the jump provides a set of algebraic equations that may be solved to determine its energetics and entrainment.

When the integration of the conservation equations is complete, the deposition rate along the channel is determined. It is assumed that slumping of the levees and associated changes in the channel position act to distribute the sediment uniformly across the width of the fjord during the course of the time step. Knowing the particle density and employing a porosity equation based on continental shelf sedimentation, the deposition depth is obtained as a function of distance along the fjord. Finally, the stability of the sediment distribution is examined, by infinite slope analysis, to determine if slumping in the along-fjord direction is indicated. Excess sediment in unstable regions is redistributed downslope, and the procedure is repeated until all instabilities are eliminated. The model can then proceed to the next time step. Another situation in which sediment redistribution is required is noted by Findikakis (1983) and implemented in the model. The discretization of the particle size spectrum into a finite number of size classes can produce an undesired effect. When the bottom stress at a point along the channel is close to the critical value for deposition of a size class, then unreasonable deposition rates will occur. This results in a local hump in the bottom profile. The model tests for such humps by searching for slopes adverse to the flow, and eliminates them by redistribution.

The model handles slope stability analysis through use of a critical deposition thickness. It appears, from the discussion in Findikakis (1983), that this depth is measured upward from the fjord bed present at the start of tailings disposal. The pre-existing sediments, near the heads of Boca de Quadra and Wilson Arm/Smeaton Bay, are themselves subject to slumping. Thus, it might be necessary to initialize the model with data on the shear strength and spatial and size distributions of pre-existing sediments. While this effect may not be important in the long term, given the relatively minor amount of river sediments in contrast to tailings, it seems possible that short-term impacts due to slumping should be evaluated.

The accuracy of the numerical integration is tested by using different Runge-Kutta schemes, and by varying the step size. Calibration of the model, with data from Rupert Inlet, is described by Findikakis (1983). Its application to Boca de Quadra and Wilson Arm/Smeaton Bay is discussed elsewhere in this document (Section 4.1.6 and Appendix S).

THE TIME-DEPENDENT CIRCULATION MODEL

The density current/sedimentation model described above produces information on the evolution of fjord geometry and the tailings concentration near the bed. A time-dependent model of fjord circulation is then applied to determine the velocity and density field

of the overlying water and the resulting distribution of suspended tailings material. Kowalik (1984) and Kowalik and Findikakis (1985) describe the time-dependent, finite difference model used for this purpose.

The primary assumptions are as follows:

- o The bed form does not change during the period for which the model is run. Separate runs are made for different stages in the projected history of sediment buildup, as predicted by the density current/sedimentation model described above.

- o Lateral (across-fjord) variations in current, density, and suspended sediment, at a given depth and position along the fjord, are ignored. The geometry of the fjord is approximated by a series of rectangular cross-sections of variable width and depth; i.e., vertical sidewalls and a flat bottom. The result is a two-dimensional representation in the plane of the fjord axis. Side-arms to the fjord are treated as wider sections. There is no provision for modeling freshwater inflow, except at the head of the fjord.

- o The effects of earth rotation (the Coriolis effect) are ignored. Given the narrow width of fjord systems, this is reasonable. The horizontal scale over which rotational effects become noticeable is called the Rossby Radius of Deformation and is typically a few tens of kilometers for barotropic and low-mode internal waves.

- o Vertical accelerations are small so that the vertical pressure variation is taken as hydrostatic. The Boussinesq approximation is applied, assuming that density variations are only important in the buoyancy term. The water surface is not fixed, but surface boundary conditions are applied at its undisturbed (horizontal) level.

- o Turbulence is parameterized through eddy viscosity and diffusivity parameters. The horizontal eddy coefficients are given as constants, while the vertical eddy coefficients are functions of water column stability (the Richardson number), velocity shear, and distance from the surface or bottom boundaries.

- o Density is dependent on salinity only, and the equation of state is linear. Buoyancy fluxes through precipitation, surface heating and cooling, and evaporation are neglected. Suspended sediment is treated as a passive contaminant, not altering the density structure. Its concentration responds to advection, settling due to gravity (represented by a hindered Stokes settling velocity as described for the sedimentation model), and turbulent diffusion based on the same eddy coefficients as for salinity.

- The model is driven by specified salinity structures at the mouth of the fjord, by wind stress at the free surface, and optionally by semidiurnal tides. The salinity at the mouth is time-dependent, with linear interpolation between monthly conditions based on field observations. Tides, when included, are specified as a time-dependent sea level elevation, or a prescribed velocity profile at the fjord mouth. At outflow there are no diffusive fluxes of salt or suspended sediments from the fjord. River inflow at the head is an additional forcing agent, specified through boundary conditions on salinity and velocity.

- At the bed of the fjord, there is no normal component of velocity or fluxes of salt or suspended sediments. The latter excludes the loss of sediment through deposition or scouring as a source of suspended sediment. Rather, the sediment concentration at the bottom is specified as a boundary condition. The reason for this choice is not clear. Tailings fines could be spread widely throughout the fjord by the density current or in the overlying plume depicted in Figure F-7, but not explicitly treated in the model of Findikakis (1983). Fine sediments deposited on the inner slopes of sills would be subject to resuspension by the strong currents accompanying deep water renewal. The bottom boundary condition on sediment concentration sets a constant value for the inner reaches of the fjord, with zero beyond. The constant value employed is 20 mg/l, based on data from Rupert Inlet. Later examination of these data (EPA 1988) has suggested that 600 mg/l would be a more appropriate choice. However, since the results were presented as percentages of the bed concentration, it is not difficult to reinterpret model predictions.

The numerical solution is in the form of finite differences on a rectangular grid of variable mesh, illustrated in Figure F-9. Vertical grid spacing is typically 20 m in the vertical for the deep water and 5 m closer to the surface where the strongest gradients are found. Horizontal grid spacing is typically 1,000 m, but may be modified to more accurately represent sills. The salinity, vertical and horizontal velocity components, and eddy coefficients are evaluated at space-staggered points within the grid (see Figure F-9). Following Ramming and Kowalik (1980), the momentum conservation equation is split along the vertical and horizontal directions to avoid numerical instabilities associated with the variable grid spacing. The horizontal portion is solved explicitly and is subject to the Courant, Friedrich, and Lewy condition that restricts the time step to at most 13 seconds. The vertical portion and both portions of the split salinity and sediment transport equations are solved implicitly. This removes the stability limit, and time steps 10 times larger than those needed for the momentum equation are employed for the transport equations. Further details of the numerical procedure are given by Kowalik (1984) and Kowalik and Findikakis (1985).

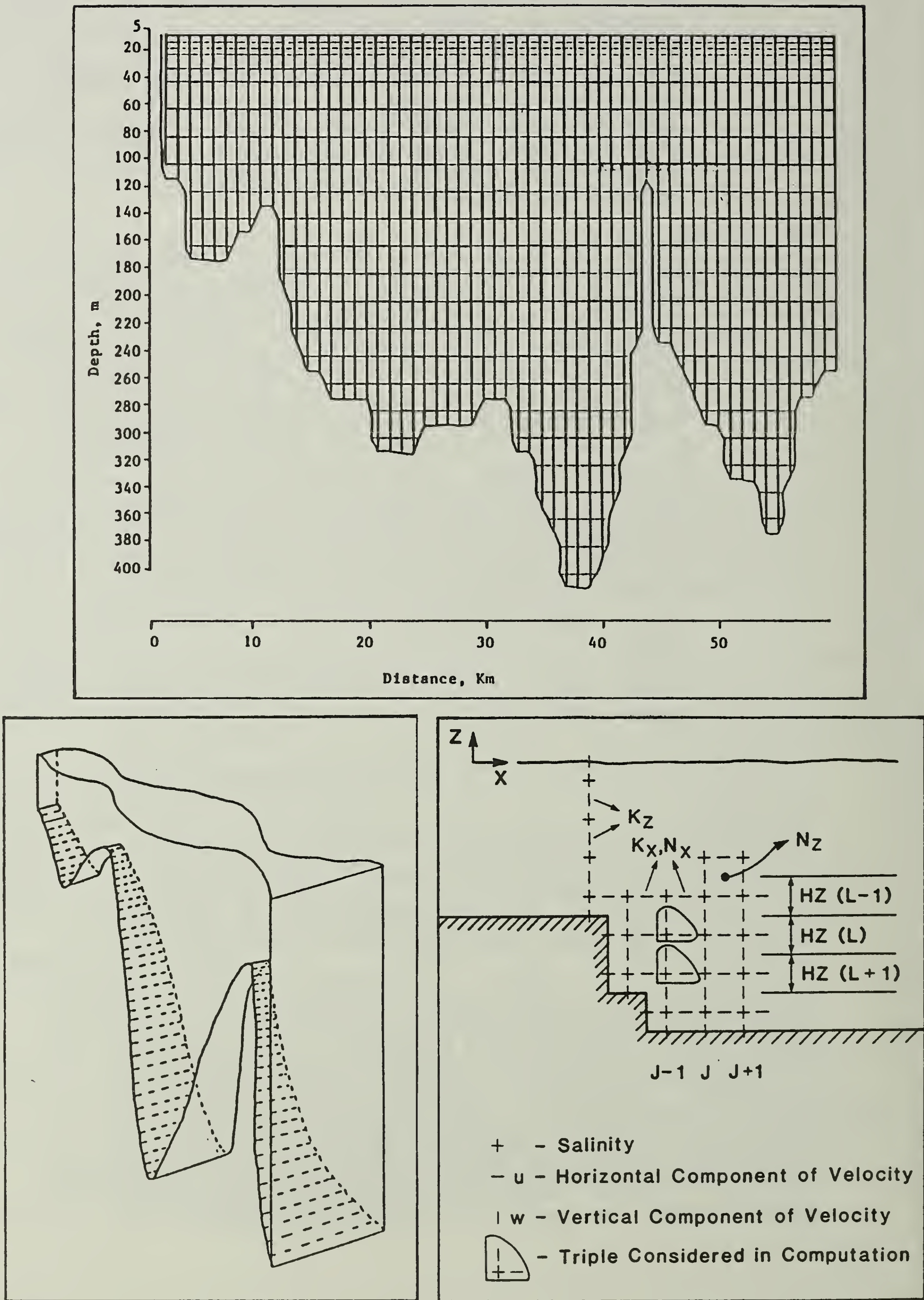


FIGURE F-9
FINITE DIFFERENCE GRID FOR THE TIME-DEPENDENT FJORD CIRCULATION MODEL
Adapted from Ryan (1983) and Kowalik (1984)

The application of the model to Wilson Arm/Smeaton Bay is described by Kowalik and Findikakis (1985). Two simulations of the summer deep water renewal season were made, with and without tidal forcing. The June salinity structure at eight points in the fjord, as determined by CTD observations, were linearly interpolated to provide an initial condition. The velocity field was started from a state of rest. Subsequent observations in July, August, and September, at the outer sill, were interpolated to provide the time-varying open boundary condition, while measurements within the fjord were used to judge the success of model predictions. The results are discussed elsewhere in this document (Section 4.1.6 and Appendix S).

THE STEADY-STATE CIRCULATION MODEL

The implementation of a detailed, time-dependent numerical model, such as that described above, is expensive in terms of both human and computer resources. An unfortunate result may be that an extensive sensitivity study of the model, to explore the influence of the various parameters it contains, is not feasible. Compounding the problem is the fact that the database of field observations used to calibrate a model is rarely comprehensive enough to define the full range of variability available to the physical system being modeled. Thus, although reasonable agreement between model predictions and field data may exist, the ability of the model to replicate other, possibly rare, sets of conditions cannot be guaranteed. In short, the task of risk assessment may not be adequately addressed by the model calibration process, particularly in the case of more complex numerical models.

In an attempt to assess the ecological risks associated with submarine disposal of mine tailings in fjords, a stochastic approach has been applied by the U.S. Environmental Protection Agency (EPA 1988). This is based on a steady-state, finite difference statement of the conservation of suspended sediment in each of a grid of rectangular cells representing the fjord. Each cell spans the width of the fjord, as in the time-dependent model of Kowalik (1984). At steady-state, the net loss of suspended matter by a cell, due to vertical and along-fjord advection, vertical and horizontal diffusion, and particle settling, must be balanced by a source term within the cell. This balance is illustrated schematically in Figure F-10. If the volume fluxes, settling velocity, eddy diffusion coefficients, and source terms are known, then a set of linear equations results, which can be solved for the unknown sediment concentrations associated with each cell.

The approach taken by EPA (1988) is to adopt, for the deep water renewal and nonrenewal seasons, circulation patterns that conform to available current meter measurements and to use best judgments where data are sparse. The patterns are required to satisfy mass continuity. Such patterns are generated for Boca de Quadra and Smeaton Bay, for the present topography, and those predicted by the density current/ sedimentation model for year 20 and year 55 of disposal operations. A suitable settling velocity is chosen by restricting consideration to the finest 10 percent of the tailings size spectrum (median diameter 5 μm). All larger particles are assumed to be rapidly

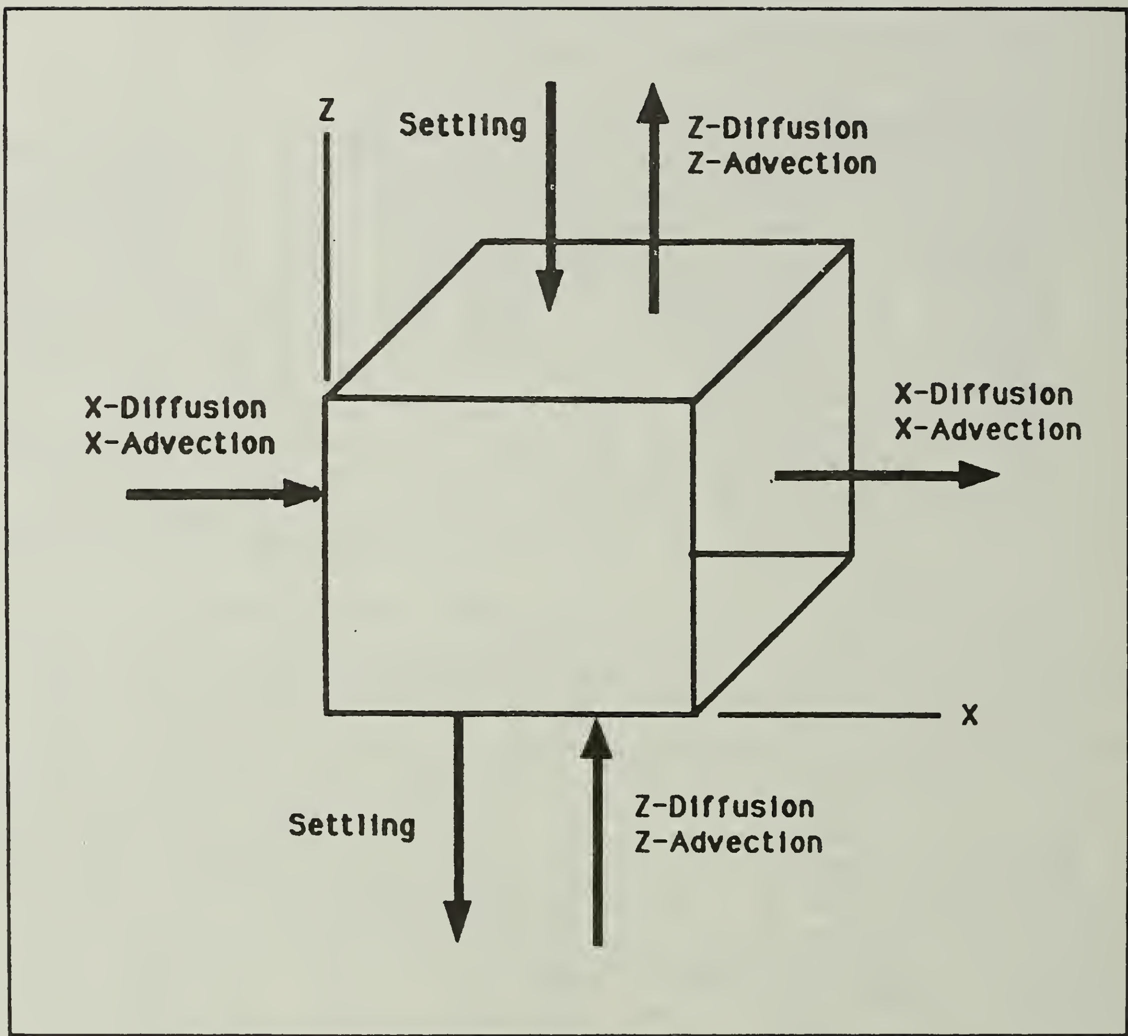


FIGURE F-10

ADVECTIVE AND DIFFUSIVE TAILINGS FLUXES
FOR A CELL IN THE STEADY-STATE MODEL
Adapted from EPA (1988)

lost by deposition. The source term is based on the known discharge rate for these fine particles, distributed equally among the lowest layer of grid cells to a distance of 10 km from the outfall.

The horizontal and vertical eddy diffusivities (K_x and K_z respectively) are treated as random variables, with assumed probability distributions based on values reported in the literature. For K_z an algebraic dependence on water column stability is employed (Zison et al. 1978) whose coefficients are assigned probability distributions. The mean and standard deviations of water column stability for Boca de Quadra and Smeaton Bay have been computed as a function of depth and time of year (see Appendix S). Then, in a Monte Carlo procedure, numerous realizations of the distribution of suspended sediment concentration are generated by randomly selecting K_x and K_z values and solving the linear equation set for each choice. The statistics of the concentrations predicted for a cell, or for a selected region within the fjord, are interpreted as indicators of the range of conditions that might be observed were long-term records available.

The tabulated results for mean suspended sediment concentration, and the probability of exceeding water quality criteria for heavy metals, suggest that there is only a limited impact on the upper water column. This conforms to the predictions of the time-dependent modeling results, and may be the result of the circulation pattern imposed. The reversed estuarine circulation pattern observed in these fjords acts to inhibit the surfacing of sediment plumes, and represents a conservative choice from the point of view of risk assessment.

SUMMARY

The problem of predicting dispersal of fines resulting from submarine disposal of mine tailings in fjords has been subdivided into three tasks. The behavior of the tailings plume in the immediate vicinity of the outlet is complex. In the absence of suitable mathematical models and field data for validation, a physical model was used to investigate the near field. The dilution of the plume within the near field was found to vary in an unsteady manner with the nature of the flow. Tailings material from Quartz Hill test operations were employed in the physical model. None of the physical model runs revealed a "split-plume," in which fines separate from the coarser fraction as depicted in Figure F-7. The least dilution (with factors ranging from 5-9) is associated with channel-type flow, and the degree of dilution decreases with decreasing bottom slope. The results from the near-field model are applied to the far-field modeling as a boundary condition on the density of the plume entering the "far field." The ambient water in the model tank was quiescent, thus excluding possible effects, such as tidal currents, in modifying tailings behavior. Model scaling is chosen to replicate the density current and sediment particle trajectories. Shear stress of the deposited material is not scaled, so that the burying of the outlet that occurred in several runs gives no information on whether this is likely to occur under actual conditions.

Large-scale deposition of tailings material along the bed of the fjord is modeled as a quasi-steady state process. A density current, confined to a channel, carries material downslope, and the conservation rules are stated as a set of first-order, ordinary differential equations. Channel geometry is based on stream morphology and observations in Rupert Inlet, and features such as arrested flows and hydraulic jumps are explicitly represented. The equations are integrated numerically, using accurate Runge-Kutta schemes, and the resulting deposition rates are used to predict changes in bed form. The channel is assumed to meander, through slumping of the levees, so that the deposition is averaged across the width of the fjord in each time step. Depending on the time step chosen, and the possible existence of preferred channels due to sill geometry, this procedure may tend to underestimate downfjord transport of tailings material. Downfjord slope instabilities are corrected by redistribution of material, rather than actual slumping, and there is no representation of the cloud of fines that such slumping might generate (see Figure F-7). Scouring within the channel is not treated. As with the physical model, the overlying water is treated as quiescent, so that fines dispersal associated with fjord circulation is not represented. The product of this phase of the modeling is a time history of the fjord bottom topography, and near-bottom tailings concentration in each of several size classes.

The final phase of modeling represents the dispersal of fines through the water column. Tailings fines are advected and diffused as a passive contaminant, with a known settling velocity. Two approaches have been taken. The first is a time-dependent circulation model, with optional forcing by wind stress, tides, and prescribed boundary conditions. The density structure, and resulting velocity field, of the overlying water is computed on a two-dimensional grid along the axis of the fjord. Lateral variations are ignored. Explicit representations of sediment deposition and resuspension are not included. A constant concentration of suspended tailings along the fjord bottom is applied as a boundary condition, and concentrations throughout the fjord are plotted as percentages of this limiting value. Although measurement has shown that bottom currents associated with deep water renewal are often sufficient to cause resuspension, this process is not included in the time-dependent circulation model. Neither can large-scale slumping, and the associated turbidity currents, be represented. These are a potential source for large quantities of fines. The model has only been used to simulate summer conditions, since this is the season for which most field data exist. Predictions should also be made for deep water nonrenewal conditions. Spin-up of the velocity field from rest may be responsible for the difficulties encountered in replicating the evolution of the density field. The implementation of the numerical scheme is efficient, with only one equation solved explicitly. Larger time steps can then be employed for the bulk of the computation. Nonetheless, models of this type are expensive to run over long simulation periods, and the results presented do not fully address the requirements for risk assessment.

A steady-state model of the advection, diffusion, and settling of tailings fines has also been formulated. While many processes are unlikely to reach steady state, the major advantage of this model choice is that its evaluation is inexpensive. It has been applied in a Monte Carlo mode, to facilitate risk assessment by representing poorly known physical processes with probability distributions, rather than specific coefficient values. A large number of "realizations," based on random selection of the diffusion parameters, are summarized statistically. The results are interpreted in terms of probabilities of exceeding water quality criteria in selected regions of the fjord.

The use of stochastic methods in modeling fjord processes is not new. For example, Gade (1973) has treated intermittent deep water renewal in some Norwegian fjords (at intervals of 3-10 years) as a random process, governed by the supply of dense water at sill depth and the rate of mixing in the fjord. While presenting some interesting possibilities, the Monte Carlo risk assessment approach of EPA (1988) appears to still be in a state of development, and several aspects of the description are unclear. For example, the density field, and hence currents within the fjord, are dependent on eddy processes, so that holding the circulation pattern fixed while varying K_x and K_z is not realistic. The stochastic treatment could be applied to the hydrodynamic equations also. The predicted tailings dispersal pattern for a parameter set corresponding to the time-dependent model choice would have been useful for comparison purposes.

The introduction of a source term in the steady-state model, as opposed to the specification of bottom suspended sediment concentration as a boundary condition in the time-dependent model, opens possibilities that could be explored further. For example, scouring of fines, deposited in the previous nonrenewal period, could be included. The poorly known erodability factor and shear stresses for deposition and resuspension might be assigned probability distributions. Extensions of the steady-state model, to include perhaps stochastic forcing, might yield information on the conditions under which the reversed estuarine circulation might break down. The steady-state assumption does, however, place limits on the applicability of the model.

CHEMICAL OCEANOGRAPHY

TAILINGS DISCHARGE

The tailings slurry from the mill would consist of both dissolved and solid phase constituents. The slurry would be mixed with seawater prior to discharge in the fjord. The mixing ratio is expected to vary from 1 part tailings to 1 to 4 parts seawater by weight. The 1:1 mixing ratio would result in the highest discharge concentrations; therefore, a 1:1 mixing ratio is assumed throughout these analyses. A 1:1 mixing ratio by weight is equal to a 2:1 (seawater:effluent) dilution of dissolved constituents on a volume basis as the tailings slurry would leave the thickener at 40 to 50 percent solids by weight.

Potential impacts from trace metal constituents and milling reagents in the discharge have been evaluated. The analyses performed are described in this Appendix. Worst case dissolved constituent concentrations are quantified for the near-field discharge plume before and after the inner basin of Boca de Quadra or the Smeaton Bay basin would be filled and for the below sill volume of the inner basin of Boca de Quadra prior to filling. Far-field concentrations are discussed qualitatively as the far-field dilution of constituents cannot be quantified at this time.

PLUME BEHAVIOR

Near-field dilution has been estimated from the preliminary results of physical modeling of the discharge plume performed by the Iowa Institute for Hydraulic Research at the University of Iowa (U.S. Borax 1984a). The near-field model studies indicate that the plume behaves in a coherent fashion (does not break up in the vicinity of the (outfall). Therefore, dissolved constituents would travel with the plume as it entrains water. However, dissolved materials appear to be diluted more rapidly than the suspended material.

The dilutions utilized to calculate near-field concentrations resulting from the tailings discharge are shown in Table F-1. In general, suspended fines should not rise above a depth of 70 m due to density stratification and therefore would not be extrained in the water drawn into the seawater mixing box. Thus, a sufficient volume of clean seawater would always be available to achieve these dilutions (Bechtel 1984e). These dilutions have been determined by assuming that the outfall would be on a 25 degree slope. If the outfall is placed on a lesser slope, dilutions would be decreased.

Following discharge, the plume entrains water and constituent concentrations decrease with distance from the outfall. However, due to the restricted circulation and relatively small volume of the inner basin below sill depth, continued dilution of dissolved constituents in the plume would be reduced after the plume enters this basin. That is, further dilution of dissolved constituents (entrainment of clean water) would be restricted until the dissolved constituents are carried into the central basin. As the inner basin is filled, the below sill dissolved concentrations would tend to approach the concentration of the plume entering the below sill volume. As discussed in Section 3.1.6, Physical Oceanography, there is a small and nearly continuous outflow from the below sill volume of the inner basin during nondeep water renewal periods. During deep water renewal periods, there is inflow of water from the central basin to the below sill inner basin. Therefore, a build-up of dissolved constituents is not expected and concentrations should not exceed the concentrations predicted for the plume entering the below sill volume. These concentrations are discussed in the following section.

TABLE F-1

NEAR-FIELD DISCHARGE PLUME DILUTIONS FOR OUTFALL ON A 25 DEGREE SLOPE 1/

	Dissolved Constituents		Suspended Solids	
	Above Sill and Worst Case Below Sill Inner Basin Prior to Basin Filling	Worst Case After Inner Basin is Filled 2/	Above Sill and Worst Case Below Sill Inner Basin Prior to Basin Filling	Worst Case After Inner Basin is Filled 2/
Dilution	14:1	5:1	8:1	3.5:1
Horizontal Distance from Outfall (m)	100	50	100	50
Vertical Distance from Outfall (m)	50	25	50	25

1/ Bechtel 1984b. Dilutions are presented as parts seawater to one part tailings discharge. These are the dilutions achieved at the outfall and do not include premixing.

2/ Due to build-up of deposited sediments in the vicinity of the outfall, the vertical distance travelled by the near-field discharge plume would be reduced from 50 m to 25 m after the inner basin is filled. The reduced dilutions shown would occur at a horizontal distance of 50 m from the outfall; however, dilutions reported for a horizontal distance of 100 m from the outfall would continue to be achieved.

By the time the inner basin has been filled, tailings solids would have been deposited to a depth of approximately 75 m in the vicinity of the outfall. This build-up would restrict initial plume dilution at the seabed in the near-field zone because the vertical distance traveled by the plume would be reduced. Dilutions estimated for a horizontal distance of 100 m from the outfall would continue to be achieved. The plume would continue to entrain water as it travels across the filled inner basin towards the central basin. Thus, dissolved plume concentrations would decrease with distance from the outfall. The continued entrainment of water or the additional dilution achieved with distance has not been quantified. Continual dilution of the plume in the central basin should be ensured because of the large volume of the central basin, annual renewal, and natural removal mechanisms for dissolved constituents.

NEAR-FIELD DISSOLVED TRACE ELEMENT CONCENTRATIONS

The mixed tailings discharge would consist of both dissolved and solid phase constituents. With respect to bioavailability, the dissolved state is of primary concern as the uptake of trace metals by organisms occurs chiefly in the dissolved phase (Forstner and Salomons 1981, p. 245; Morel and Morel-Laurens 1981, p. 842). The dissolved effluent concentrations reported by U.S. Borax (1984b) are shown in Table F-2. Dilution of only the dissolved effluent concentrations, however, may not provide realistic *in-situ* concentrations for all constituents because the release and adsorption interactions between particulate matter and dissolved constituents would not be represented.

The results of tailings leaching and bioassay analyses performed by EVS Consultants (1984a) provide the best available data with which to assess the behavior of the Quartz Hill mine tailings in the fjord environment. The leaching tests were conducted by mixing 6 kg of tailings solids with 6 liters of tailings decant and 16 liters of seawater. This mixture approximates the discharge to the fjord (a 50 percent by weight solid tailings slurry mixed 1:1 with seawater).

The EVS data are the only available data for which leaching experiments utilizing the Quartz Hill mine tailings were conducted for longer than 24 hours. The results of the EVS (1984a) leaching analyses are presented in Table F-3. The behavior observed was used to determine the dissolved trace element concentrations in the discharge and resultant near-field concentrations. The discharge concentrations used to calculate near-field dissolved concentrations are shown in Table F-2. The manner in which these concentrations were determined is described below.

Based on the EVS leaching experiments, the behavior of the trace elements was classified into four groups as follows:

1) Metals that do not exhibit release or that remain below detection during the experiment (includes metals for which removal from solution was exhibited). These metals were identified by comparing

TABLE F-2

DISSOLVED CONCENTRATIONS IN TAILINGS EFFLUENT AND DISCHARGE

	Tailings Effluent Dissolved Concentration a/ (μg/l)	Baseline Seawater b/ (μg/l)	Discharge Concentration (μg/l)
Ag	7	0.002	2.3 c/
As	6.8	1.4	3.2 c/
Cd	15	0.08	5.05 c/
Cr	34	0.15	11.43 c/
Cu	35	0.30	11.87 c/
Fe	1790	1.0	0.20 d/
Hg	1.2	0.001	0.40 c/
Mn	330	2.0	550 d/
Mo	1080	9.0	500 d/
Ni	290	0.40	96.9 c/
Pb	120	0.01	40.0 c/
Se	6.6	0.10	2.27 c/
Zn	77	0.50	26 c/

a/ U.S. Borax 1984b.

b/ Riley and Skirrow 1965.

c/ After conservative mixing of tailings effluent and seawater in the mixing box. Calculated as 2 parts seawater mixed with 1 part tailings effluent.

d/ Concentration observed on Day 0 of tailings leaching experiments (EVS 1984a).

TABLE F-3

RESULTS OF EVS TAILINGS LEACHINGS ANALYSES

PARAMETER		Control Seawater	Tailings Decant 0 Days	Tailings Decant 90 Days	Leach Test - Day 0 Rep.# 1	Leach Test - Day 0 Rep.# 2	Leach Test - Day 5 Rep.# 1	Leach Test - Day 5 Rep.# 2	Leach Test - Day 10 Rep.# 1	Leach Test - Day 10 Rep.# 2
Sulfate	SO_4	2,700.			1,820.	1,820.	2,000.	1,850.	1,870.	1,840.
Nitrate + Nitrite	N	0.50			0.59	0.90	0.33	0.31	0.44	0.22
Ortho-Phosphate	P	0.13			0.034	0.027	0.013	0.008	0.008	0.008
Total Kjeldahl Nitrogen	N	0.10			0.32	0.34	0.38	0.34	0.33	0.29/0.29
Total Organic Carbon	C	4.0		11.0	5.5	4.5	2.1	2.6	1.3	1.8
Dissolved Organic Carbon	C	2.1			4.5	3.6	1.8	1.5	L0.5	L0.5
Total Cyanide	CN	L0.010			L0.010	L0.010	L0.010	L0.010	L0.010	
Weak Acid Dissociable	CN	L0.010			L0.010	L0.010	L0.010	L0.010	L0.010	L0.010
Base/Neutrals					n.d.		n.d.		n.d.	
Antimony	Sb	0.1	2.8	2.7	1.5	1.4	1.1	0.9	0.9	1.0
Arsenic	As	1.1	0.6	0.3	0.5	0.5	0.2	0.2	0.2	0.2
Cadmium	Cd	0.95/1.2	L0.5	L0.5	0.02	0.05	L0.01	0.11	0.10	0.13
Chromium	Cr	L1.	L1.	L1.	L1.	L1.	L1.	L1.	L1.	L1.
Cobalt	Co	0.12/0.10	L1.		0.72	0.65	0.35	0.59	0.68	1.0
Copper	Cu	1.37	L1.	2.0	0.73	0.70	0.47	0.63	0.94	2.3
Iron	Fe	0.8/0.7	1,790.	L30.	0.2	1.3	0.4	0.9	1.2	2.7
Lead	Pb	0.7/0.6	L1.	L1.	L0.05	L0.05	0.30	L0.05	0.55	0.08
Manganese	Mn	170.	,330.	360.	550.	550.	950.	1,080.	1,240.	1,400.
Molybdenum	Mo	120.	1,080.	440.	470.	480.	490.	470.	500.	480.
Nickel	Ni	5.5/5.0	4.	2.	9.7	8.8	4.8	6.3	8.1	9.4
Selenium	Se	0.17	0.12	L0.1	0.17	0.20	L0.10	L0.10	L0.10	L0.10
Silver	Ag	L0.5	L0.5		L0.5	L0.5	L0.5	L0.5	L0.5	L0.5
Zinc	Zn	6.8/6.1	5.	L5.	1.8	2.2	2.0	3.1	2.0	2.3
Total Mercury	Hg	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05
pH		8.2	8.0		8.3	8.3	8.1	8.1	8.2	8.1
Total Suspended Solids		12.8			439.	301.	65.5	29.5	62.7	47.3
Total Dissolved Solids		29,662.			25,375.	26,753.	24,257.	25,055.	24,001.	23,051.
Turbidity (NTU)		2.4			204.	148.	24.	5.3	20.	16.
Conductivity (umhos/cm)		28,000.	300.		26,000.	26,000.	25,500.	25,000.	23,000.	23,000.
Salinity (ppt)		26.	0		24.	24.	23.5	23.	21.	21.

Note:
- all metals are on a dissolved basis except mercury
- the metal results are expressed as ug/L and the other parameters are expressed as mg/L unless indicated otherwise

L = less than
n.d. = none detected
[a]tailings decant water resampled and analyzed 90 days after first sample collection and analysis

From EVS(1984a) page 15.

The concentrations expected as a result of the decant/seawater mix to the observed concentrations throughout the 10-day leaching experiment: Ag, As, Cr, Hg, Se.

2) Metals that exhibit rapid release and do not increase over the 10-day period: Mo, Ni (Ni concentrations declined on Day 5, but were comparable to initial mixed concentrations on Day 10).

3) Metals that exhibit slow release over the 10-day period. Most of these metals appeared to be removed from solution following mixing of the slurry with seawater and then exhibited release. The observed removal is regarded as a possible effect of abnormally high dissolved concentrations in the control seawater and behavior is assessed by examining the tendency for release between Day 0 (following mixing and removal) and Day 10: Cd, Cu, Fe, Pb, Zn.

4) Metals that exhibit both rapid and continual release: Mn.

Calculations of dissolved constituent concentrations in the discharge for the above groups have been performed as follows:

Group 1 - No release: Dissolved concentrations calculated by assuming conservative mixing of tailings effluent with natural seawater.

Group 2 - Rapid release: Dissolved concentrations calculated by assuming that the dissolved concentration in the 1:1 seawater/slurry discharge is equal to the Day 0 concentration observed in the leaching test.

Group 3 - Slow release over the 10-day period: Discharge concentrations are calculated by assuming conservative mixing of effluent and natural seawater. Release from tailings is a far field process and is assumed to occur in the below sill volume.

Group 4 - Both rapid and continual release: Discharge concentrations are calculated by assuming that the dissolved concentration in the 1:1 seawater/slurry mixture is equal to the Day 0 concentration in the leaching test. Continued release from tailings is a far-field process and is assumed to occur in the below sill volume.

Exceptions to the above assumptions regarding dissolved constituents in the discharge were made for Fe and Ni. Dissolved iron exhibited rapid removal upon mixing with seawater; control seawater and decant concentrations were similar to concentrations expected in the fjord and tailings effluent. Therefore, the concentration observed on Day 0 of the leaching test is used for the concentration of the 1:1 seawater/slurry mixture. Dissolved effluent Ni concentrations reported by U.S. Borax are much higher in the effluent than concentrations in the tailings decant utilized by EVS (1984a) for leaching experiments. Conservative mixing calculations indicate that the reported effluent Ni

concentration and Ni concentrations expected in natural seawater result in higher discharge concentrations than those measured on Day 0 of the leaching experiment. The higher dissolved concentration has been used.

The dissolved concentrations calculated using the dilutions shown in Table F-1 and the discharge concentrations shown in Table F-2 are presented in Columns 4 and 5 of Table F-4. As shown by comparing columns 4 and 5 to columns 8-10 in Table F-4, dissolved constituent concentrations in the near-field discharge plume would be below both the EPA criteria and the Alaska drinking water standards at a horizontal distance of 100 m from the outfall and a vertical distance of 50 m from the outfall for all metals except mercury. For a reduced vertical distance (25 m after inner basin filling), dissolved Ni concentrations would exceed the EPA criteria. All other dissolved concentrations except Hg would be below the criteria and drinking water standards at this distance. The dissolved concentrations shown in Table F-4 are considered to be conservative estimates of concentrations in the mixing zone and below sill volume because removal from the dissolved phase has not been quantified. The dissolved phase is of primary concern with respect to bioavailability. Therefore, in the worst case analysis it is assumed that the metals remain in the dissolved state. It should be noted that many of the dissolved metal ions would be subject to natural removal mechanisms such as adsorption onto suspended particulates or formation of solids by precipitation reactions. Removal processes may result in lower dissolved concentrations than those predicted by dilution calculations.

The EPA criteria for Ag, As, Cr, Cd, Cu, Hg, Ni, Mn, Pb, Se, and Zn are specified in terms of total recoverable metal concentration, which includes both dissolved and solid phase metal content. As shown by comparison of columns 6 and 7 with columns 8 and 9 in Table F-4, total concentrations of As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, and Zn would exceed the EPA criteria at a horizontal distance of 100 m and vertical distances of 50 m and 25 m from the outfall. After the inner basin has been filled, Ag would also exceed the EPA criteria at a vertical distance of 25 m from the outfall. The distribution of suspended solids in the turbidity plume and the distance at which total recoverable concentrations would be below the EPA criteria are discussed below.

DISTRIBUTION OF SUSPENDED SOLIDS

Following discharge, suspended solids would begin to settle and deposit on the fjord bed. Peak suspended solids concentrations would occur near the bed (Bechtel 1984b). Suspended tailings concentrations measured at distances of 300 m and 1,000 m from the Island Copper mine outfall, directly in line with the plume, are presented in Table F-5a (Rescan 1984b). The 300 m and 1,000 m distances represent straight line distances from the end of the outfall; therefore, the exact linear distance travelled by the plume is unknown. On the day that these concentrations were measured, the Island Copper tailings discharge was approximately 25 percent smaller than that planned for Quartz Hill. The size distribution of tailings particles is similar for both discharges. Assuming a linear relationship between discharge size and

TABLE F-4

NEAR-FIELD DISSOLVED METAL CONCENTRATIONS
FOR THE PROPOSED DISCHARGE TO THE INNER BASIN
(all concentrations μg/l except as noted)

		Near-Field Dissolved Concentrations			Total Recoverable Concentrations 2/		EPA Criteria			
Metal (1)	Baseline (2)	Discharge 1/ (3)	Above Sill 100 m From Outfall and Worst Case Below Sill Inner Basin (4)	Worst Case After Inner Basin is Filled (5)	Above Sill 100 m From Outfall and Worst Case Below Sill Inner Basin (6)	Worst Case After Inner Basin is Filled (7)	Total Recoverable 3/ (8)	Total Recoverable 4/ (9)	Alaska Drinking Water Standards 5/ (10)	Criteria Exceeded (11)
Ag	0.002	2.33	0.15	0.39	1.47	3.03		2.3	50	After basin filled
As	1.40	3.20	1.52	1.70	116.02	227.18	36 6/		50	Yes
Cd	0.08	5.05	0.41	0.91	13.9	27.8	9.3		10	Yes
Cr	0.15	11.43	0.90	2.03	102.85	205.88	50 7/		50	Yes
Cu	0.30	11.87	1.07	2.23	509.7	1019.3	2.9 8/		1000	Yes
Fe	1.0	0.20	0.95	0.87					300	No
Hg	0.001	0.40	0.028	0.068	0.51	1.02	0.025		2	Yes
Mn	2.0	550	38.53	93.33	2494.55	5004.31		100 9/	50	Yes
Mo	9.0	500	41.73	90.83						No criteria
Ni	0.4	96.93	6.84	16.49	187.57	369.17		7.1		Yes
Pb	0.01	40.01	2.68	6.68	231.7	463.3	5.6		50	Yes
Se	0.10	2.27	0.24	0.46	1.26	2.50		54 10/	10	No
Zn	0.50	26.00	2.20	4.75	535.11	1070.34		58	5000	Yes

1/ Concentration of the 1:1 (seawater:slurry) by weight or 2:1 by volume (seawater:water effluent only) discharge. See Appendix F, Table F-2.
2/ Calculated by multiplying suspended solids concentration (g/l) by the extractable metal content of tailings solids (μg/g) and adding the dissolved concentration to this product.
3/ Four day average concentration not to be exceeded more than once every 3 years (EPA 1985). Total recoverable concentration which is operationally defined as the concentration of metal in an unfiltered sample following treatment with hot dilute mineral acid (EPA 1979c).
4/ EPA criteria for 24-hour average or concentration not to be exceeded at any time (EPA 1980h, l, m, n). Total recoverable concentration which is operationally defined as the concentration of metal in an unfiltered sample following treatment with hot dilute mineral acid (EPA 1979c).
5/ Alaska DEC specifies that either EPA criteria or Alaska Drinking Water Standards, whichever is less, shall apply.
6/ Trivalent arsenic; forms of arsenic in the discharge unknown.
7/ Hexavalent chromium; forms of chromium in the discharge are unknown.
8/ One hour average concentration not to be exceeded more than once every 3 years on the average (EPA 1985).
9/ EPA 1976.
10/ Total recoverable inorganic selenite; form of selenium in discharge is unknown.

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TABLE F-5

a) SUSPENDED TAILINGS CONCENTRATIONS DOWNSTREAM OF ISLAND COPPER DISCHARGE IN RUPERT INLET, B.C. a/
(all concentrations in g/l)

Depth (m)	Depth Above the Bottom (m)	Concentration at 300 m	Depth (m)	Depth Above the Bottom (m)	Concentration at 1,000 m
45	28	0	43	48	0.0034
50	23	0.004	49	42	0.0045
55	18	0.012	55	36	0.0119
58	15	0.055	61	30	0.0071
61	12	0.50	67	24	0.0190
64	9	0.55	73	18	0.0150
67	6	0.60	79	12	0.0170
70	3	0.60	85	6	0.120
73	0	2.0	91	0	0.630

b) PREDICTED TAILINGS CONCENTRATIONS DOWNSTREAM OF QUARTZ HILL DISCHARGE, BOCA DE QUADRA
(all concentrations in g/l)

Depth Above the Bottom (m)	Concentration at 300 m	Depth Above the Bottom (m)	Concentration at 1,000 m
18	0.014	48	0.00425
15	0.069	42	0.0011
12	0.62	36	0.0149
9	0.69	30	0.0089
6	0.75	24	0.0238
3	0.75	18	0.0188
0	2.5	12	0.0212
		6	0.150
		0	0.788

a/ Rescan 1984b.

concentration of suspended particles, concentrations in Boca de Quadra would be approximately 25 percent greater than those observed in Rupert Inlet. The depth of discharge is the same for both mines. The bottom depth at the time the Island Copper profiles were measured was 73 m versus approximately 150 m in the inner basin at the beginning of the project and 100 m following basin filling. Therefore, the distribution of concentrations expected in Boca de Quadra are presented in Table F-5b as distance above the bottom.

The EPA criteria for Ag, As, Cd, Cr, Cu, Hg, Ni, Mn, Pb, Se, and Zn are specified in terms of total recoverable or active metal concentration, which includes both dissolved and solid phase metal content. As shown in Table F-4, total concentrations of As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, and Zn would exceed the criteria at a horizontal distance of 100 m from the outfall and vertical distances of 50 m and 25 m from the outfall. After the inner basin is filled, Ag would also exceed the criteria at a vertical distance of 25 m from the outfall. For these metals, the maximum recoverable solid phase concentration permitted is equal to the criteria minus the predicted dissolved concentration. The estimated extractable metal content per gram of tailings solids was used to estimate the suspended tailings concentration at which the criteria would be approached; the extractable metal content of the tailings solids is shown in Table F-6. At suspended tailings solids concentrations above the maximum value, the EPA criteria would be exceeded. The maximum permissible suspended solids concentrations are compared to the estimated suspended solids concentrations at 300 m and 1,000 m from the outfall in Table F-7 for two distances above the bottom. After the inner basin has been filled and the plume is not entering a restricted basin, most trace element concentrations should be below the EPA criteria by a distance of 1000 m from the outfall. Copper concentrations may remain above the criteria within the turbidity plume at this distance, but should be below the criteria at a distance of approximately 12 m above the bottom.

FAR-FIELD BEHAVIOR OF TAILINGS DISCHARGE

Following discharge and near-field dilution, trace metals may continue to be released from the tailings solids. EVS 1984b (p. 30) report that leaching analyses of tailings effluent indicate release of Mn and Mo in excess of amounts leached from control sediments. With time (1 month for Mo and 2 months for Mn) concentrations declined to within the range of control values.

Hoff et al. (1982) conducted leaching experiments for 30 days with tailings from the Island Copper mining operation and reported that Mn and Ni increased slowly and remained somewhat elevated at termination of the experiment. A graph of the Ni release versus time indicates that Ni concentrations had reached a maximum by the tenth day and declined somewhat thereafter. The length of time required to reach maximum Mn concentrations is not reported and it is not known if Mn concentrations declined from the maximum, even though concentrations remained somewhat elevated. It is assumed that the 10-day leaching tests are sufficient to evaluate release of Mn.

TABLE F-6

COMPARISON OF TAILINGS SOLIDS METAL CONTENT WITH NATURAL SEDIMENTS

	Total 1/ Tailings Content (μg/g)	Extractable Tailings Content (μg/g)	Mean Extractable 2/ Content, Surficial Sediments Boca de Quadra (μg/g)	Reported Sediment Ranges (μg/g)
As	10.9	4.8 3/		5 4/
Cd	2.4	0.6 2/	<1	
Cu	69	22 2/	32	
Cr	10	4.4 3/		48 5/
Fe	12,000	8,704 2/	16,320	
Pb	47	<10 2/	15	
Hg	<.05 ND	<0.022 3/		0.18 5/
Mo	120	120 2/	2	
Mn	462	106 2/	550	
Ni	17.7	7.8 2/		37 5/
Se	0.1	0.044 3/		<1.5 6/
Ag	0.13	0.057 3/		0.4 5/
Zn	46	23 2/	60	

1/ U.S. Borax 1984b.

2/ Burrell 1983, Chapter 7, Table 7-20.

3/ Estimated as 44 percent of total content. Average of extractable divided by total content for metals analyzed by Burrell is equal to 44 percent.

4/ Waldichuk and Buchanan 1980, p. 28, Rupert Inlet.

5/ Goyette and Christie 1982a, pp. 25-28, Alice Arm.

6/ Dexter et al. 1981, p. 282 for Puget Sound, Washington.

ND = Not detected.

TABLE F-7

COMPARISON OF MAXIMUM PERMISSIBLE SUSPENDED TAILINGS CONCENTRATIONS WITH CONCENTRATIONS AT 300 m AND 1000 m FROM THE OUTFALL
(all concentrations in g/l)

	Suspended Tailings Concentration				
	Above Which Total Recoverable	At 300 m from Outfall		At 1000 m from Outfall	
Metal	EPA Criteria is Exceeded 1/	15 m Above Bottom	12 m Above Bottom	12 m Above Bottom	6 m Above Bottom
Ag	37.72	0.069	0.62	0.021	0.15
As	7.19	0.069	0.62	0.021	0.15
Cd	14.82	0.069	0.62	0.021	0.15
Cr	11.16	0.069	0.62	0.021	0.15
Cu	0.08	0.069	0.62	0.021	0.15 2/
Hg	None 3/	0.069	0.62	0.021	0.15
Mn	0.58	0.069	0.62	0.021	0.15
Ni	0.034	0.069	0.62	0.021	0.15 4/
Pb	0.29	0.069	0.62	0.021	0.15
Zn	2.43	0.069	0.62	0.021	0.15

1/ Calculated by subtracting the dissolved concentration at 100 m from the outfall from the criteria and using the extractable metal content of the tailings solids to estimate the total suspended tailings solids concentration above which the criteria would be exceeded.

2/ At this suspended solids concentration, the EPA criteria for copper would be exceeded. As shown, suspended solids concentration would be approximately 0.021 g/l at 12 m above the bottom; therefore, Cu concentration will be below the criteria at a distance of 12 m above the bottom.

3/ Dissolved mercury concentration exceeds the criteria at 100 m from the outfall; therefore, the mercury in the solid phase is not calculated for minimum initial dilutions. However, assuming a slight increase in dilution to 20:1 and an extractable Hg content equal to half the reported detection limit, calculations indicate that mercury concentrations in the turbidity plume would be below criteria at a distance of 1,000 m from the outfall.

4/ At this suspended solids concentration, the total recoverable Ni criteria would be exceeded. However, the suspended solids concentration above which the criteria would be exceeded has been estimated by subtracting the dissolved concentration at 100 m from the outfall from the criteria because the dilution of dissolved constituents at a distance of 300 m is unknown. If the dissolved Ni concentration is reduced from 6.84 μg/l to 5.9 μg/l by a distance of 1000 m from the outfall, the criteria would be met within the turbidity plume. It is probable that the far-field dilution following inner basin filling would be such that dissolved Ni concentration would be below 5.9 μg/l by a distance of 1000 m from the outfall.

In the experiments of Hoff et al. (1982), all other metals exhibiting release reached maximum concentrations very rapidly. The rapid release of Fe, Cu, and Pb reported by Hoff et al. (1982) (maximum concentration within 3 hours) is not exhibited in the leaching experiments performed by EVS (1984a). Additionally, Cd and Zn did not exhibit release in the experiments of Hoff et al. (1982). These differences may be a function of the much lower tailings concentration used by Hoff et al. (1982) relative to the concentrations used in the EVS (1984a) experiments and to differences in control seawater and tailings effluent concentrations.

As described for Ni, Hoff et al. (1982) report that concentrations of other metals exhibiting release (Cu, Pb, and Fe) declined with time. Final levels of these metals were at or below initial concentrations. They propose scavaging by $Fe(OH)_3$ as a plausible mechanism to account for the eventual removal of these metals. They state that the final concentrations were independent of the concentration of tailings added which suggests that the mechanism of removal is one of precipitation rather than adsorption. The potential for removal of dissolved metal ions is extremely important with respect to the ambient dissolved concentrations that may result from tailings leaching.

At this time, data which would enable the removal rate of leached dissolved materials to be quantified are not available. The dissolved concentrations of metals exhibiting release in the EVS (1984a) experiments (either rapidly on Day 0 or continuously between Day 0 and Day 10) remained elevated or continued to increase throughout the experiment. This behavior suggests that at tailings concentrations as high as those used for the leaching experiment (concentration approximating those of the discharge), removal rates are less than the leaching rate, resulting in a net increase in dissolved constituents. Concentrations of solid tailings would be substantially reduced by entrainment following discharge. Therefore, removal by adsorption and/or precipitation may exceed leaching for many metals as observed by Hoff et al. (1982).

At present, the best available means of assessing potential water quality impacts arising from tailings leaching is the change observed in water quality at similar mining operations in Alice Arm, B.C., and Rupert Inlet, B.C. Analyses show that concentrations of Cd, Pb, and Zn (both soluble and total) are slightly elevated in the Alice Arm water column in the region of the mid-depth cloud (Burling et al. 1983, p. 37). Concentrations of dissolved lead are elevated by up to 0.008 μg/l, cadmium by up to 0.040 μg/l, zinc by up to 0.425 μg/l. While lead isotope ratios point to the Kitsault ore as the primary source of enrichment, the relative proportions of B.C. Molybdenum versus AMAX tailings is not clear. These increases are relatively small and do not result in ambient concentrations that exceed EPA criteria. Increases on this order in Boca de Quadra or Smeaton Bay would not change the conclusions drawn about near field and turbidity plume concentrations.

It must be noted that concentrations of Cd, Pb, and Zn are much higher in the Kitsault mine tailings than expected in the Quartz Hill tailings. However, the quantity of tailings discharged would be much greater at the Quartz Hill mine than at the AMAX Kitsault mine. The

effect of these differences on potential water quality impacts is unknown. Dissolved concentration increases in Boca de Quadra, on the order of those observed in the Alice Arm mid-depth plume, would not result in ambient concentrations above the EPA criteria.

Marine monitoring data on the effect of discharging Island Copper mill tailings into Rupert Inlet, B.C., indicate that only Mn has shown a slight but statistically significant increase in the water column (Poling 1982, p. 77). Dissolved Mn concentrations in Rupert Inlet show an average increase of approximately 3-4 μg/l (Pelletier 1982, p. 235). There is no apparent increasing trend in Mn concentrations with time. This could be a consequence of the high flushing rate and vigorous tidal exchange in Rupert Inlet. Flushing rates in Boca de Quadra are much lower than in Rupert Inlet. Therefore, the lack of substantially elevated dissolved concentrations in Rupert Inlet cannot be regarded as conclusive evidence that elevated concentrations in Boca de Quadra would not occur.

LONG-TERM RELEASE FROM SEDIMENT

As shown in Table F-6, most trace element concentrations in the tailings solids are comparable to concentrations in the natural sediments. At natural sediment concentrations, most trace elements remobilized in the reduced sediment layer are precipitated or adsorbed in the oxygenated surficial sediments, and are therefore not released into the water column. Remobilized manganese is known to be released into overlying waters because the rate of Mn (II) oxidation is relatively slow; the buried solids would not have high Mn concentrations relative to natural sediments. Therefore, Mn release should not be higher than that occurring naturally. Although the concentrations of Mo would be elevated in tailings solids, it would be expected that released Mo would be immobilized as a sulphide phase (Burrell 1983, p. 28). Interstitial dissolved Mo concentrations in the sediments of Smeaton Bay/Wilson Arm are below detection within the anoxic sediment zone. Solid phase molybdenum concentrations are at a maximum around 8-10 cm below the sediment surface. These observations indicate that Mo is removed from the dissolved phase in the deep sediments and should not be released into overlying waters.

DISSOLVED OXYGEN

The primary concern regarding the discharge of milling reagents to the fjord is the potential impact on dissolved oxygen concentrations in the basin's below sill depth. Several of the reagents are organic compounds that would consume oxygen during degradation. The degree to which oxygen may become depressed below natural levels depends primarily on the degree to which compounds degrade, the rate at which degradation occurs, the rate that oxygen is replenished in the basin, and the residence time of basin waters. None of these factors are well known.

Biological Oxygen Demand (BOD) laboratory results provided by U.S. Borax (1985a) indicate that the maximum BOD_5 of the tailings effluent is 30 mg/l. This value was used in conjunction with the plume volume

to compare the total BOD of the discharge. The computed BOD was compared to the oxygen contained in the plume to evaluate the potential for dissolved oxygen depressions in the fjords. The maximum BOD_5 of the plume is computed to be 28 percent of the dissolved oxygen entrained within the plume; these calculations are detailed in Table F-8. The discharge plume will contribute a net gain in dissolved oxygen to the below sill volume. Depressions in dissolved oxygen concentrations are, therefore, not expected.

TABLE F-8

CALCULATION OF OXYGEN REQUIRED FOR BIODEGRADATION OF MILLING REAGENTS

Plume Volume

- Discharge Volume is 39.8 MGD (1.505×10^{8} l/day)
- In the mixing chamber discharge is diluted 1:1 for a total volume of 79.6 MGD (3.01×10^{8} l/day). Assuming a minimum dilution of 10:1 at the outfall, total discharge volume is 30.01×10^{8} l/day.

Biological Oxygen Demand (BOD^5)

- Maximum BOD_5 of plume is 30 mg/l (U.S. Borax 1985a).
- Assuming no BOD_5 of the seawater used for dilution in the mixing chamber and at the outfall, 1:1 premix results in BOD_5 = 15 mg/l. Assuming a minimum dilution of 10:1 at the outfall, resultant BOD_5 of discharge plume is 1.5 mg/l.

Total BOD^5 of Discharge

Total BOD_5 = 1.5 mg/l 30.01×10^{8} l/day = 45.02×10^{8} mg/day.

Total 0^2 Entrained in Discharge

Assuming a minimum dissolved oxygen concentration of 5 mg/l in surface water of fjord, O_2 is added in the mixing chamber and at the outfall.

Total O_2 entrained = 31.52×10^{8} l/day X 5 mg/l = 158×10^{8} mg/day.

Percent of Entrained 0^2 Consumed by BOD

$$\frac{\text{Total } BOD_5}{O_2 \text{ Entrained}} \times 100 = \frac{45}{145} \times 100 = 28 \text{ percent}$$

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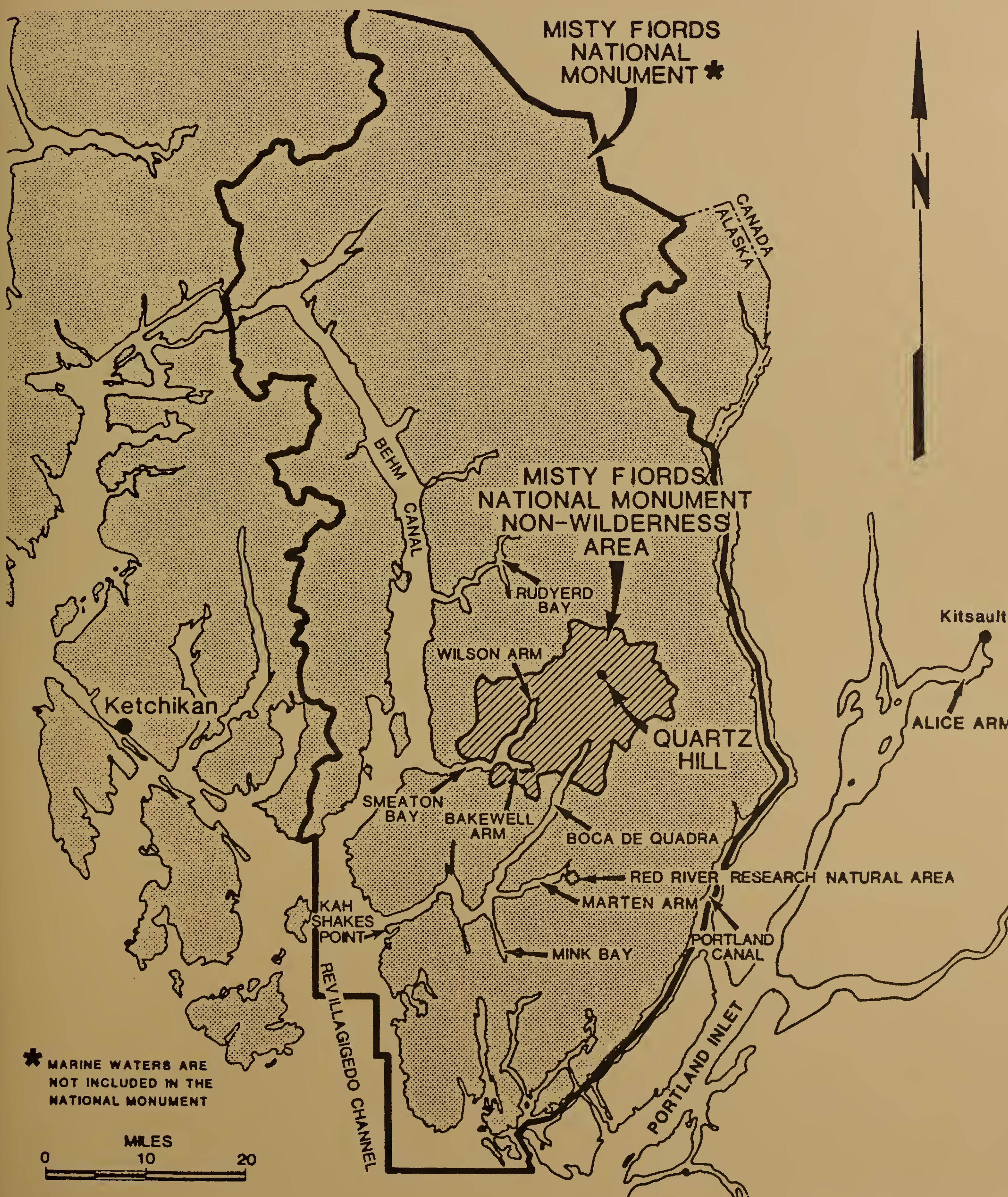
APPENDIX G
FRESHWATER AND MARINE ECOLOGY



APPENDIX G

FRESHWATER AND MARINE ECOLOGY

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APPENDIX G

SECTION 1

TABLE 1-1

COMMON AND SCIENTIFIC NAMES OF ANADROMOUS AND RESIDENT FISHES FOUND IN THE VICINITY OF QUARTZ HILL

Common Name	Scientific Name
Pink salmon	*Oncorhynchus gorbusha*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Chinook salmon	*Oncorhynchus tshawytscha*
Sockeye salmon	*Oncorhynchus nerka*
Steelhead rainbow trout	*Salmo gairdneri*
Cutthroat trout	*Salmo clarki*
Dolly Varden char	*Salvelinus malma*
Threespine Stickleback	*Gasterosteus aculeatus*
Sculpin	*Cottus* sp.
Lamprey	*Lampetra* sp.
Eulachon	*Thaleichthys pacificus*

APPENDIX G

SECTION 2

TABLE 2-1

ESCAPEMENT CORRECTION FACTORS

Salmon escapement counts are conducted by means of fixed winged aircraft, helicopter, or on foot. Escapement counts generally underestimate the actual escapement of salmon because the observer does not see all the fish that are present in a stream. The level of observer efficiency varies as a result of experience, familiarity with stream, stream conditions, and salmon species. Therefore, an escapement correction factor is used to adjust peak escapement counts in order to estimate the total salmon escapement. Correction factors are derived from studies that compare the known escapement (based on weir counts or population estimate) to survey escapement counts. The correction factors used are the average of those reported in the literature.

Species	Correction Factor	Source
Pink and chum	2 times peak escapement	Meyer (1964)
Coho	3 times peak escapement	Flint and Zillges (1980)
Chinook	2 times peak escapement	Neilson and Geen (1981)

APPENDIX G

TABLE 2-2
PEAK ESCAPEMENT COUNTS FOR SALMON IN THE WILSON RIVER

Year	Peak Escapement Counts by Species a/			
	Pink	Chum	Coho	Chinook
1948	(155,240) b/	(50,000)	(1,700)	(100)
1949	(126,300)	(12,000)	(11,000)	(1,000)
1950	(101,500)	(11,000)	(6,000)	(10)
1951	(79,600)	(5,500)	(2,250)	(25)
1952	(72,200)	(700)	(100)	(50)
1953	(40,000)	(10,000)	(150)	(90)
1954	(26,500)	(3,500)	... c/	...
1955	(20,000)	(200)	...	...
1956	(100,000)	(6,000)	...	...
1957	(9,100)	(4,200)	...	...
1960	22,500	500	...	...
1961	10,800	700	...	...
1962	57,000	...	...	...
1963	46,200	10,000	...	10
1964	65,050	10,000	...	...
1965	36,225	2,000	...	50
1966	93,500	2,500	...	60
1967	8,100	100	...	8
1968	56,200	7,000	...	...
1969	12,000	250	...	10
1970	177,200	...	...	...
1971	174,500	...	...	...
1972	108,400	...	...	...
1973	128,000	7,700	...	30
1974	153,000	(300)	...	...
1975	170,000	25	...	7
1976	106,010	...	...	...
1977	286,000	...	...	...
1978	131,000	(450)	...	...
1979	(64,000)	(1,105)	...	36
1980	192,006	(300)	...	...
1981	135,003	4,006	350	(76)
1982	188,003	503	...	300
1983	330,000	300	...	178
1984	305,000	273	...	133
1985 e/	269,800	10,703	...	...
Mean d/	194,151	1,797	350	122
Standard Deviation d/	84,969	3,339	0	107

a/ Information compiled from Martin (1959), Kissner (1983), and House (1983b, 1985a).
b/ Incomplete survey of accessible spawning area.
c/ No data.
d/ Based on counts for period 1974-1985.
e/ Based on preliminary data.

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TABLE 2-3

PEAK ESCAPEMENT COUNTS FOR SALMON IN THE BLOSSOM RIVER

Year	Peak Escapement Counts by Species[a]			
	Pink	Chum	Coho	Chinook
1949	(15,570)[b]	(500)	(1,000)	...[c]
1950	(6,000)	(3,000)	...	...
1951	30,000	(650)	(500)	...
1952	(6,900)	(4,500)	...	...
1953	(450)	(3,500)	...	(2)
1954	(500)	(300)	...	...
1956	3,000	...	...	500
1957	300	100	...	100
1962	4,100	...	...	...
1963	(800)	...	...	825
1964	6,000	1,000	...	...
1965	6,000	1,000	...	...
1966	26,000	(2,000)	...	(200)
1967	(1,180)	...	...	...
1968	77,000	5,000	...	...
1969	1,100	400	...	...
1970	58,300	3,000	...	100
1971	5,000	2,000	...	...
1972	48,000	(3,200)	...	700
1973	1,600	2,590	...	...
1974	40,000	(2,000)	...	166
1975	11,000	700	...	153
1976	26,800	(2,279)	(485)	68
1977	(45,000)	...	...	(112)
1978	34,700	...	...	(143)
1979	7,600	...	...	54
1980	65,800	4,003	...	89
1981	51,400	8,000	1,150	159
1982	(128,376)	307	1,350	(345)
1983	64,000	100	...	589
1984	297,000	4,106	...	508
1985[e]	40,003	8,003	...	501
Mean[d]	67,640	3,278	995	241
Standard Deviation[d]	78,729	3,042	453	192

a/ Information compiled from Martin (1959), Kissner (1983), and House (1983b, 1985a).
b/ Incomplete survey of accessible spawning area.
c/ No data.
d/ Based on counts for period 1974-1985.
e/ Based on preliminary data.

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TABLE 2-4
PEAK ESCAPEMENT COUNTS FOR SALMON IN THE KETA RIVER

Year	Peak Escapement Counts by Species a/			
	Pink	Chum	Coho	Chinook
1948	(75,000) b/	(15,000)	... c/	(500)
1949	(22,000)	(6,000)	(3,000)	...
1950	(60,000)	(6,500)	(2,500)	(210)
1951	(71,500)	(2,400)	(300)	(120)
1952	(24,800)	(950)	...	(462)
1953	(7,600)	(1,520)	...	(156)
1954	(12,500)	(6,000)	...	(300)
1955	(2,200)	...	...	1,000 d/
1956	(36,700)	(10,000)	(40)	(1,500) d/
1957	(4,000)	(5,000)	...	(500) d/
1960	20,500	2,500	...	...
1961	6,700	500	...	(44)
1962	100,000	...	...	...
1963	(9,200)	9,000	...	(30)
1964	20,000	27,000	...	...
1965	8,200	7,000	...	...
1966	29,500	5,500	...	75
1967	1,950	1,475	...	86
1968	78,000	5,200	...	...
1969	2,800	3,200	...	200
1970	138,100	15,000	...	...
1971	4,000	2,000	...	2
1972	134,000	10,000	...	...
1973	4,550	5,680	...	...
1974	21,000	8,750	...	(25)
1975	9,300	7,000	...	203
1976	10,400	7,600	470	84
1977	34,000	30,000	(250)	(230)
1978	39,200	13,500	(52)	392
1979	3,200	(5,300)	(250)	426
1980	33,500	10,000	...	192
1981	84,850	(3,500)	1,150	329
1982	36,000	3,000	725	(754)
1983	240,000	800	...	822
1984	160,503	16,503	...	311
1985 f/	162,503	30,003	...	258
Mean e/	69,538	11,329	482	336
Standard Deviation e/	76,692	9,760	399	241

a/ Information compiled from Martin (1959), Kissner (1983), and House (1983b, 1985a).
b/ Incomplete survey of accessible spawning area.
c/ No data.
d/ Probably includes chum salmon.
e/ Based on counts for period 1974-1985.
f/ Based on preliminary data.

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TABLE 2-5

PEAK ESCAPEMENT COUNTS FOR SALMON IN TUNNEL CREEK

Year	Peak Escapement Counts by Species[a/]			
	Pink	Chum	Coho	Chinook
1979	2,000	200	... [b/]	...
1980	1,400	600	...	...
1981	3,735	200	...	...
1982	4,000	256	...	...
1983	9,950	183	...	...
Mean	4,217	288		
Standard Deviation	3,391	177		

a/ Information compiled from VTN (1980c, 1981d, 1982f) and Anderson (1983).
b/ No data.

APPENDIX G

TABLE 2-6
PEAK ESCAPEMENT COUNTS FOR SALMON IN ARONITZ CREEK

Year	Peak Escapement Counts by Species[a/]			
	Pink	Chum	Coho	Chinook
1979	230	40	...[b/]	...
1980	209	312	...	...
1981	127	64	...	...
1982	860	65	...	...
Mean	356	120		
Standard Deviation	338	128		

a/ Information compiled from VTN (1980b, 1981b, and 1982c).
b/ No data.

APPENDIX G

SECTION 3

TABLE 3-1

COMMERCIAL CATCH OF SALMON FROM THE KETCHIKAN AREA
(MANAGEMENT DISTRICTS 1-4)
1975-1985[a]

Year	Chinook	Coho	Pink	Chum
1975	116,456	210,814	2,395,203	325,842
1976	83,910	226,024	4,343,006	485,826
1977	50,267	270,738	8,335,833	375,384
1978	82,309	543,122	16,384,091	613,292
1979	84,020	393,197	4,142,402	266,083
1980	52,513	397,223	13,335,800	790,773
1981	61,054	501,608	12,225,525	295,182
1982	87,476	657,796	12,631,692	815,479
1983	76,684	706,192	29,365,144	456,861
1984	55,873	580,259	18,799,811	1,234,513
1985	52,892	760,159	27,278,924	968,423
1975-1985 Average	73,041	477,012	13,567,039	602,514

a/ Annette Island catch figures are included in this table, data from House (1983c, 1985b).

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TABLE 4-1

JUVENILE SALMONID ABUNDANCE, ESTIMATED POPULATION SIZE, AND ESTIMATED ADULT RETURN FOR TRIBUTARY CREEKS IN THE VICINITY OF QUARTZ HILL

	Juvenile Salmonids in Sample Reach									Juvenile and Adult Salmonids in Entire Stream								
	Reach Length[a/] (m)	Number Captured[b/]				Population Estimate[c/]				Stream Length[d/] (m)	Juvenile Population Estimate[e/]				Estimated Adult Return[f/]			
		CO[g/]	CH	DV	ST	CO	CH	DV	ST		CO	CH	DV	ST	CO	CH	DV	ST
North Creek	100	15	1	4	-	30	2	8	-	800	240	16	64	-	16	1	2	-
Beaver Creek	85	35	-	25	1	70	-	50	2	320	263	-	188	8	17	-	5	1
Raspberry Creek	75	51	16	105	1	102	32	210	2	400	544	171	1120	11	35	10	28	1
No. 3 Creek[h/]	-	-	-	-	-	-	-	-	-	640	870	273	1792	17	57	16	45	2
Tunnel Creek	75	68	13	129	-	136	26	258	-	1400	2539	485	4816	-	166	29	121	-
White Creek	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hill Creek	75	60	21	222	-	120	42	444	-	1000	1600	560	5920	-	104	34	149	-
Aronitz Creek	125	15	1	4	7	30	2	8	14	1000	240	16	64	112	16	1	2	12

a/ Anderson (1983b).
b/ VTN (1983c, Table 1-2).
c/ Based on capture efficiency of .51 computed from VTN (1980c, Table 3.2-5) for Hill Creek
d/ Length of anadromous habitat from either VTN (1982l, Table 3-1) or Benda (1983c).
e/ Equals: Stream length/sample reach length x sample population estimate.
f/ - Coho fingerling to adult survival average of 6.53 percent, computed from Gray et al. (1978, p. 21).
- Chinook smolt to adult survival average of 6.0 percent, from Kissner (1983).
- Dolly Varden juvenile to adult survival average of 2.5 percent, computed from fry and smolt survival data in Armstrong (1983).
- Steelhead smolt to adult survival average of 11 percent, from Jones (1983).
g/ CO = coho, CH = chinook, DV = Dolly Varden, ST = steelhead.
h/ Assumed equal to densities measured in Raspberry Creek.

TABLE 4-2

JUVENILE DOLLY VARDEN CHAR ABUNDANCE, ESTIMATED POPULATION SIZE, AND ESTIMATED ADULT RETURN FOR BLOSSOM RIVER BELOW BEAVER CREEK AND KETA RIVER BELOW HILL CREEK

	Juvenile Dolly Varden in Sample Reach					Juvenile and Adult Dolly Varden in Entire Stream		
	Study[a] Reach	Reach[a] Length (m)	Number[a] Captured		Population[b] Estimate	Stream[c] Length (m)	Juvenile[d] Population Estimate	Estimated[e] Adult Return
Blossom River	BL-BA-12	47	11		100			
	BL-BA-15	37	104		945			
	BL-BA-14	43	32		290			
	Mean	42		Mean	445	8700	92,178	2,304
Keta River	KE-BA-1	49	14		127			
	KE-BA-5	46	25		227			
	KE-BA-4	34	9		82			
	Mean	43		Mean	313	6900	50,225	1,255

a/ Data from VTN (1980c, Tables 3.1-1 and 3.2-1).
b/ Based on capture efficiency of .11 computed from VTN (1980c, Table 3.2-5) for Dolly Varden in Blossom River.
c/ From VTN (1982l, Figure 3-2)
d/ Equals: Stream length/sample reach length x sample population estimate.
e/ Dolly Varden juvenile to adult survival average of 2.5 percent, computed from fry and smolt survival data in Armstrong (1983).

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APPENDIX G

SECTION 5

ESTIMATION OF SEDIMENT IMPACTS ON SALMON

The estimated impacts of sediment from the proposed project were based on the difference between the average total production of salmon under existing and impacted conditions. This computation was performed by calculating the egg deposition (calculated as 1/2 [average escapement multiplied by average fecundity]) for both existing and impacted conditions. Additional egg loss from the sediment is calculated according to methods detailed in Appendix G, Section 6. The average egg-to-adult survival for each species was multiplied by the egg deposition to yield average total return. Data used in these calculations are from the following sources.

- Average escapement is from text Table 3-9 for all streams except Tunnel Creek; coho and chinook escapement for Tunnel Creek is computed as the difference between estimated return and estimated harvest from text Table 3-10.

- Average fecundity for pink and chum is from Hunter (1959, Table 4); coho from Cederholm et al. (1981, Table 7); chinook is from Wydoski and Whitney (1979, page 59); and Dolly Varden is from Armstrong (1983).

- Additional egg loss is from Appendix G, Table 6-1. Under existing conditions, the rate of egg mortality during the incubation period is accounted for in the average egg-to-adult survival estimate.

- Average egg-to-adult survival is computed as the product of survival rates for each life history phase. Survival estimates are from research studies or unpublished data as indicated in Appendix G, Table 5-1.

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APPENDIX G

TABLE 5-1

SURVIVAL ESTIMATES USED IN THE COMPUTATION OF
EGG-TO-ADULT SURVIVAL

	Pink Salmon		Chum Salmon	
Egg to Fry	.0563	Hunter 1959 (Table 16)	.0626	Hunter 1959 (Table 16)
Fry to Adult	.067	Hunter 1959 (Table 23)	.0235	Hunter 1959 (Table 21)
Egg to Adult	.0037		.0014	

	Coho Salmon	
Egg to Fry	.299	Tagart 1976
Fry to Yearling	.150	Salo and Cederholm 1981 (Table 1)
Yearling to Adult	.045	Shaul et al. (in press)
Egg to Adult	.0020	

	Chinook Salmon	
Egg to Smolt	.053	Paul Kissner, Personal Communication, 1983
Smolt to Adult	.060	Paul Kissner, Personal Communication, 1983
Egg to Adult	.0032	

	Dolly Varden char	
Egg to Adult	.0011	Robert Armstrong, Personal Communication, 1983

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APPENDIX G

TABLE 5-2

ESTIMATED IMPACT OF SEDIMENT FROM PROPOSED PROJECT ON THE AVERAGE SALMON PRODUCTION AND AVERAGE HARVEST FROM THE BLOSSOM RIVER BELOW BEAVER CREEK AND WILSON RIVER BELOW CONFLUENCE WITH THE BLOSSOM RIVER

	Pink		Chum		Coho		Chinook		Dolly Varden		All Salmon
Average Escapement[a/]	65,680		2,440		1,466		191		2,304		
Assume 50 Percent Female	32,840		1,220		733		96		1,152		
Average Fecundity	1,584		2,468		3,000		5,000		1,846		
Average Egg Deposition	52,018,560		3,010,960		2,199,000		480,000		2,126,592		
Condition	Existing	Impacted	Existing	Impacted	Existing	Impacted	Existing	Impacted	Existing	Impacted	Impacted
Additional Egg Loss From Increased Sediment (percent)	0	9	0	9	0	17	0	15	0	6	
Net Egg Deposition	52,018,560	47,336,890	3,010,960	2,739,973	2,199,000	1,825,170	480,000	408,000	2,126,592	1,998,996	
Average Egg to Adult Survival	.0037	.0037	.0014	.0014	.0020	.0020	.0032	.0032	.0011	.0011	
Average Total Return	192,468	175,146	4,215	3,836	4,398	3,650	1,536	1,306	2,339	2,198	
Average Total Loss		17,322		379		748		230		141	18,820
Commercial Harvest Loss (percent)		11,605 (67)		246 (65)		598 (80)		184 (80)			12,633
Sport Harvest Loss (percent)						11 (1.5)		5 (2)			16

a/ Escapement for pink, chum coho, and chinook equals the sum of the Blossom and Wilson river average escapements adjusted by 47 percent and 6 percent, respectively, for the portion of spawning area below Beaver Creek (from text Table 3-11). Escapement for Dolly Varden from Appendix G, Table 4-2. Average total loss equals the difference between total returns for existing and impacted conditions.

TABLE 5-3

ESTIMATED IMPACT OF SEDIMENT FROM ALTERNATIVES THAT INCLUDE A TAILINGS PIPELINE AND ACCESS ROAD ON THE AVERAGE SALMON PRODUCTION AND AVERAGE HARVEST FROM THE KETA RIVER BELOW HILL CREEK[a/]

	Pink		Chum		Coho		Chinook		Dolly Varden		All Salmon
Average Escapement[b/]	75,694		13,238		1,070		512		1,255		
Assume 50 Percent Female	37,847		6,619		535		256		627		
Average Fecundity	1,584		2,468		3,000		5,000		1,846		
Average Egg Deposition	59,949,648		16,335,692		1,605,000		1,280,000		1,157,442		
Condition	Existing	Impacted	Existing	Impacted	Existing	Impacted	Existing	Impacted	Existing	Impacted	Impacted
Additional Egg Loss From Increased Sediment (percent)	0	9	0	9	0	23	0	15	0	6	
Net Egg Deposition	59,949,648	54,554,179	16,335,692	14,865,479	1,605,000	1,235,850	1,280,000	1,088,000	1,157,442	1,087,995	
Average Egg to Adult Survival	.0037	.0037	.0014	.0014	.0020	.0020	.0032	.0032	.0011	.0011	
Average Total Return	221,814	201,850	22,870	20,812	3,210	2,472	4,096	3,482	1,273	1,196	
Average Total Loss		19,964		2,058		738		614		77	23,451
Commercial Harvest Loss (percent)		13,376 (67)		1,338 (65)		590 (80)		491 (80)			15,795
Sport Harvest Loss (percent)						11 (1.5)		12 (2)			23

a/ Alternatives are: North Meadow mill with Boca de Quadra tailings disposal (Keta alternative), and North Meadow mill with on-land tailings disposal.

b/ Escapement for pink, chum, coho, and chinook equals 74 percent (from text Table 3-11) of the average escapement. Escapement for Dolly Varden from Appendix G, Table 4-2. Average total loss equals the difference between total returns for existing and impacted conditions.

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APPENDIX G

SECTION 6

METHODOLOGY FOR COMPUTING SALMON EGG MORTALITY

Increased sedimentation of spawning gravels will reduce the portion of eggs surviving to the emergence stage. Egg loss is computed as the difference between estimated survival during existing conditions and survival during impacted conditions (Appendix G, Table 6-1). Estimated survival is based on the relationship between egg survival and concentration of fines in spawning gravel as reported from research studies:

- Pink and chum salmon - Koski (1975)
- Coho salmon - Cederholm and Salo (1979, Figure 13)
- Chinook salmon - Bjornn (1968)
- Dolly Varden is assumed similar to steelhead - Bjornn (1968)

The concentration of fines (size <4.0 mm or <1.0 mm) is the parameter used to estimate survival. Concentrations of fines (size <4.0 mm) present under existing conditions are from August 1982 (VTN 1982d, Table A-4) and fines <1.0 mm are also computed from samples collected in August 1982 (VTN 1983k, Appendix B).

The concentration of fines expected in the Blossom and Keta rivers under impacted conditions is based on the average quantity of fines measured on November 6, 1982 at station BL-ARC-3 after the landslide in No. 1 creek (VTN 1983k, Appendix B).

APPENDIX G

TABLE 6-1

EGG LOSSES BASED ON CONCENTRATION OF FINES IN SPAWNING GRAVEL AND SURVIVAL TO EMERGENCE OF SALMONIDS FOR EXISTING AND IMPACTED CONDITIONS IN STREAMS NEAR QUARTZ HILL

	Existing		Impacted		
	Gravel <4.0 mm (percent)	Survival (percent)	Gravel <4.0 mm (percent)	Survival (percent)	Egg Loss (percent)
PINK AND CHUM SALMON					
Blossom River	12.0	69	18.5	60	9
Keta River	11.5	69	18.5	60	9
CHINOOK SALMON					
Blossom River	12.0	79	18.5	64	15
Keta River	11.5	79	18.5	64	15
DOLLY VARDEN CHAR					
Blossom River	12.0	94	18.5	88	6
Keta River	11.5	94	18.5	88	6

	Existing		Impacted		
	Gravel <1.0 mm (percent)	Survival (percent)	Gravel <1.0 mm (percent)	Survival (percent)	Egg Loss (percent)
COHO SALMON					
Blossom River	6.1	81	11.6[a/]	64	17
Keta River	4.3 [b/]	87	11.6	64	23

a/ Assumed 50 percent of concentration for size <4.0 mm.
b/ From VTN 1982d, Table A-2.

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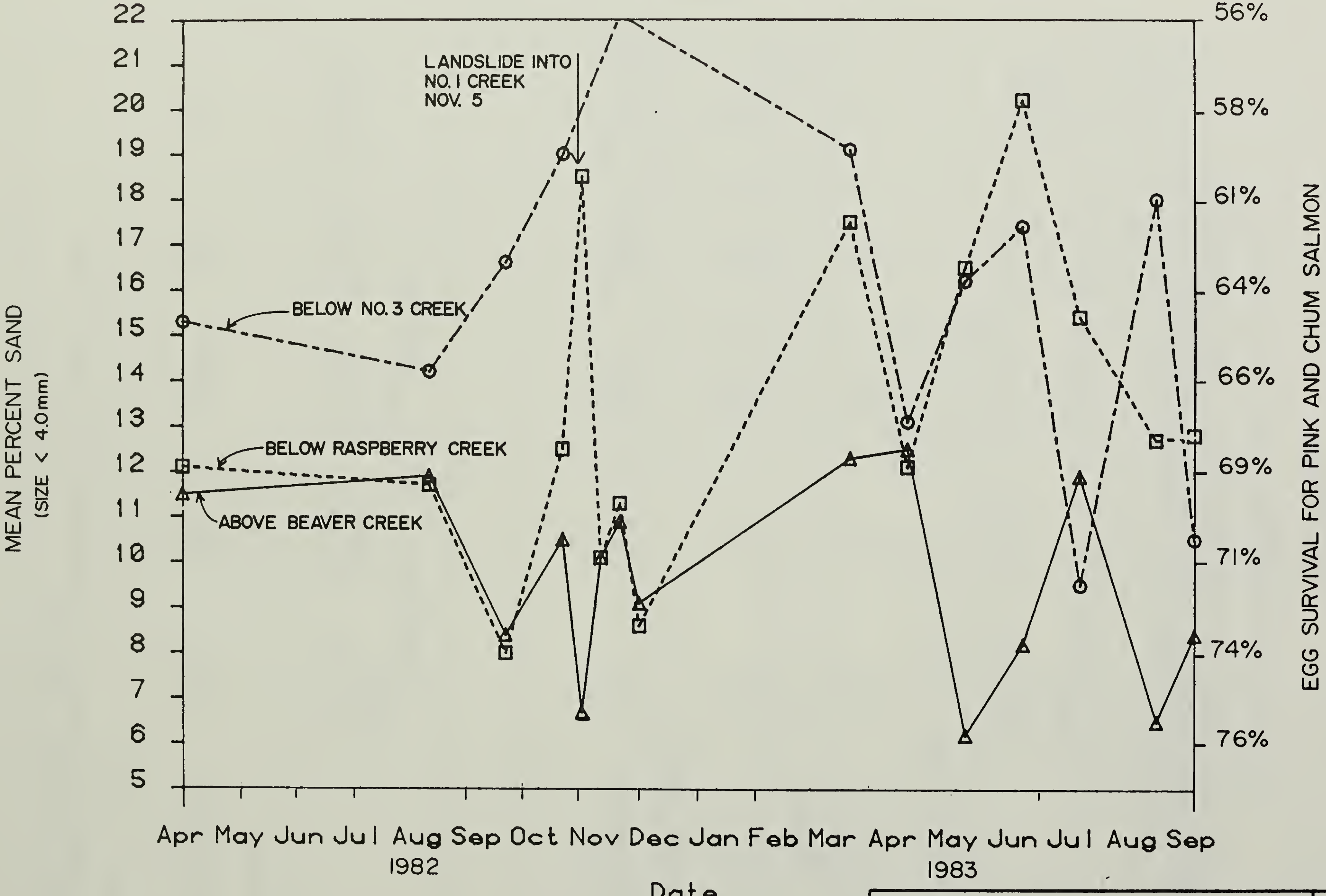
Concentration of Sand in Blossom River Spawning Gravel



NOTE : Gravel data from VTN (1983 k, appendix B). Egg survival computed from formula developed by Koski (1975).

U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE QUARTZ HILL MOLYBDENUM PROJECT MINE DEVELOPMENT EIS	FIGURE 6-1
CONCENTRATION OF SAND (SIZE 4.0mm) IN SPAWNING GRAVELS OF BLOSSOM RIVER	envirosphere company A Division of EBASCO SERVICES INCORPORATED
SOURCE ENVIROSPHERE DATE DEC 83	

APPENDIX G

SECTION 7

VALUE OF CRAB AND SHRIMP FISHERY

The following are assumptions made in estimating the total value of Boca de Quadra and Smeaton Bay crab and shrimp fishery.

1. The reported shrimp catch was exclusively pot-caught shrimp (spot and coonstripe) for these two fjords.

2. The reported catch does not include all shrimp or crab caught commercially in the two fjords because catches reported just from the larger district (District 103), which these bays are a part of, cannot be separated by subdistrict and included in this catch. Also, no sport catches are included in these data.

3. The catches do not represent the maximum potential harvest for shrimp or crab production.

4. Because of (2) and (3) above, the "best" available estimate of the fishery's value is the current shrimp and crab value and the peak catch between 1969 and 1983.

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APPENDIX G

TABLE 7-1

COMMERCIAL CATCH OF SHELLFISH AS REPORTED FOR BOCA DE QUADRA AND SMEATON BAY[a/]

	Dungeness Crab (lbs)		Shrimp (lbs)	
Year[b/]	Boca de Quadra	Smeaton Bay	Boca de Quadra	Smeaton Bay
1969	0	0	0	1280
1970	324	0	4054	0
1971	2059	0	815	2190
1972	2164	0	1190	165
1973	4523	0	0	0
1974	1765	1020	0	808
1975	5315	1036	0	0
1976	0	0	538	465
1977	4951	2615	0	25
1978	852	1088	0	0
1979	1996	188	1380	412
1980	3270	112	13,609	32
1981	1486	...[c/]	4612	...
1982	6172	...	1211	1314
1983	...	...	1196	...
Average	2325	404	1907	446
Peak	6172	2615	13,609	2190

a/ Some of these harvest values may be low because the commercial catch that was reported by the larger district (District 103), which these two fjords are part of, would not be included in these data. Location of harvests within each fjord is not known.

b/ 1969-1978 data from ADF&G (1980) and 1979-1983 data from House (1983d).

c/ No reported catch.

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APPENDIX G

TABLE 7-2

ESTIMATED VALUE FOR SOUTHEAST ALASKA,
BOCA DE QUADRA, AND SMEATON BAY
POT SHRIMP AND DUNGENESS CRAB FISHERY[a/]

POT SHRIMP - Values for SE Alaska Statistical Area A

Year	Pounds[b/]	Exvessel Value[b/] (1982$) Total	Per Pound
1982	175,600	$613,000	$3.49

DUNGENESS CRAB - Values for SE Alaska Statistical Area A

Year	Pounds[b/]	Exvessel Value[c/] (1982$) Total	Per Pound
1982	2,929,900	$2,800,000	$0.96

ESTIMATED VALUE OF BOCA DE QUADRA AND SMEATON BAY
(1982$)

	Pot Shrimp		Dungeness Crab	
	Boca de Quadra	Smeaton Bay	Boca de Quadra	Smeaton Bay
Pounds (average)[d/]	1,907	446	2,325	404
Value (average)[e/]	$6,655	$1,557	$2,232	$388
Pounds (peak)[d/]	13,609	2,190	6,172	2,615
Value (peak)[e/]	$47,495	$7,643	$5,925	$2,510

a/ Assumptions used for these calculations are shown in Appendix G, Section 7.
b/ Values and pounds of catch from Koeneman (1983b).
c/ Values of catch from Koeneman (1983b).
d/ Value from Appendix G, Table 7-1.
e/ Exvessel value calculated by using 1982 per pound values shown above.

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APPENDIX G

SECTION 8

TABLE 8-1

SEDIMENTATION POTENTIAL TO ESTUARY FROM LANDSLIDES AND ROADS

A. Wilson River Estuary

1. Assume all sediment is deposited in the estuary and that it is evenly distributed therein.

2. Assume estuarine area of 1.3 km^2 = 1,300,000 m^2.

3. Assume that 3,700 tons of sediment will enter the estuary in the first year of construction.

   a. Equals 3,356,600 kg.

4. Assume sediment specific gravity of 1.3/cm^3 (Davis and DeWiest 1966).

5. $\frac{2{,}449{,}400 \text{ kg}}{1{,}300{,}000 \text{ m}^2} = 2.5820 \text{ kg/m}^2$

   a. $\left(\frac{2.5820 \text{ kg}}{\text{m}^2}\right) \left(\frac{1{,}000 \text{ g}}{\text{kg}}\right) \left(\frac{1 \text{ m}^2}{10{,}000 \text{ cm}^2}\right)$

   $= \left(\frac{0.2582 \text{ g}}{\text{cm}^2}\right) \left(\frac{1 \text{ cm}^3}{1.3 \text{ g}}\right)$

   = 0.20 cm deep

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a/ The estimate presented considers generally a worse case scenario. Other situations such as river high runoff would carry much of the sediment beyond the estuary. But the sediment that is deposited in the estuary is not likely to be evenly distributed, so the estimate presented here is a reasonable one.

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APPENDIX G

SECTION 9

METHODS FOR CALCULATING DENSITIES (kg/km^2) OF ECONOMICALLY IMPORTANT MARINE BOTTOM FISH AND SHELLFISH LOST FROM TAILINGS DISCHARGE

A. Boca de Quadra - Dungeness crab

1) The peak average otter trawl sampling trip density[a/] from all VTN data between 1979 and 1982 from inner basin hauls (most were between 90 and 190 meters deep) and middle basin hauls (most were greater than 190 meters deep) were used as initial density and then modified as discussed below (VTN 1980c, P. A-132 through 149; 1982f, P. A-77 through 85; 1982g, P. C-35 through 60) (Appendix G, Table 9-1).

2) Inner basin catch rates (kg/24 hours) for crab pots were 1.7 to 6.4 times greater in the upper 90 meters than from 90-190 m depth range during sampling (VTN 1980c, 1982f, 1982g).

3) It was therefore conservatively assumed that density of Dungeness crabs in the upper 90 meters was 6 times greater than otter trawl catch (Appendix G, Table 9-1).

4) The density value from 1) above was used for all depth strata areas between 90 and 190 meters for inner basin and middle basin.

5) It was assumed that no Dungeness crab were below 190 meters as none had been caught in crab pots below this depth (VTN 1980c, 1982f, 1982g).

6) The density estimates (Appendix G, Table 9-1) were then multiplied directly, or modified as discussed above, times the estimated surface area (km^2) for each impacted depth strata (Appendix G, Table 9-2).

B. Smeaton Bay/Wilson Arm - Dungeness crab

1) The peak average otter trawl sampling trip density from all VTN data for 1981 and 1982 (VTN 1981d, P. C-D-5; 1982g, P. C-35 through 60) from Wilson Arm, Bakewell Arm, and Smeaton Bay were used as the initial abundance and then modified as discussed below (Appendix G, Table 9-1).

2) The crab pot catch rate shallower than 90 meters was 2.5 to 3.2 times higher than in the 90 to 190 meter depth range pots (VTN 1981d, 1982g).

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a/ Assumed width of otter trawl opening 5 meters.

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TABLE 9-1

MAXIMUM AVERAGE SAMPLING TRIP OTTER TRAWL DENSITIES (kg/km^2)a/

	Number of Trawls	Dungeness Crab	Tanner Crab	Pot Shrimp b/	Trawl Shrimp b/	Walleye Pollock	Rockfish	Flatfish
Boca de Quadra								
Inner Basin (<190 m)	29 c/	1.4040	0.8817	1.5197	9.3515	2.6743	0.1107	10.5317
Middle Basin (<190 m)	4	0 d/	0.3375	0.2837	1.4372	0 d/	0.5252	0.8164
Middle Basin (>190 m)	21 e/	0.7512 f/	0.1500	0.0312	0.3140	0.0325	0 g/	0.0737
Smeaton Bay/Wilson Arm								
Wilson Arm (<190 m)	9	1.4620	3.6098	0.4757	7.2124	0.5773	0.0227	6.8182
Bakewell Arm (<190 m)	4	0.1059	2.6706	0.1941	9.5294	0.4235	0.0020	1.8588
Smeaton Bay (<190 m)	0	h/	h/	h/	h/	h/	h/	h/
Smeaton Bay (>190 m)	3	0	0.1077	0 h/	1.3077	0 h/	0 h/	0.0009

a/ From VTN otter trawl tables and appendix tables for the sampling years 1979-1982 (VTN 1980d, 1981f, 1982b, 1982h). Assumed trawl opening, 5 m.
b/ Pandalid shrimp of the groups: Pot shrimp = spot and coonstripe; Trawl shrimp = pink, sidestripe, and ocean pink shrimp.
c/ Three of the 29 hauls were >190 m.
d/ Inner basin density used for loss estimates.
e/ Two of the 21 hauls were <190 m.
f/ Assumed no dungeness crab below 190 m for loss estimates.
g/ Used <190 m values from middle basin.
h/ Used Wilson Arm values for densities.

APPENDIX G

TABLE 9-2

ESTIMATED AREAS USED TO ESTIMATE BOTTOM ORGANISM LOSSES

	Total	Depth Range (m) 90-190	>190	>90	150-190	70-90	75-90	85-90	100-190
	Area (km²)								
Boca de Quadra									
Inner Basin	6.40	3.45	0	3.26	1.38	0.69			
Middle Basin (inner) b/	21.84	8.20	6.25	14.37	3.28	1.64			
Middle Basin (outer) b/	17.07	5.65	6.33	11.92	2.26	1.13			
TOTAL	45.31	17.30	12.58	29.55	6.92	3.46			
Smeaton Bay/ Wilson Arm									
Wilson Arm	8.28	3.70	0	3.70				0.25	
Bakewell Arm	3.61	1.63	0.35	1.63			0.33		
Smeaton Bay	15.12	4.52	6.09	10.61					4.28
TOTAL	27.01	9.85	5.44	15.94					

a/ Areas estimated from planimeter of marine charts where possible, and approximated for other depth strata.

b/ Inner portion of middle basin area extends from inner sill to approximately 3 km upfjord from Marten Arm. Middle basin area extends to Kite Island sill, exclusive of Marten Arm and Mink Bay.

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3) It was therefore assumed that density in all areas less than 90 meters were three times greater than density from 1) above. Peak density from 1) above was used as the base multiplier for all depths greater than 90 meters in all areas.

4) Wilson Arm and Bakewell Arm densities from 1) above were used for depths between 90 and 190 m. The density for Wilson Arm from 1) above was used for depths ranging between 90 and 190 meters in Smeaton Bay.

5) It was assumed no Dungeness crab were below 190 meters as none were caught by crab pots below that depth (VTN 1981d, 1982g).

6) The density estimates were then multiplied by the estimated surface area (km^2) for each depth strata (Appendix G, Tables 9-1 and 9-2).

C. Boca de Quadra - Pandalid shrimp (pot shrimp and trawl shrimp), tanner crab, walleye pollock, rockfish, and flatfish

1) The peak average otter trawl sampling trip density from the inner or middle basins from all VTN data between 1979 and 1982 for all groups of organisms listed above were used (VTN 1980b, 1982f, 1982g) (Appendix G, Table 9-1).

Spot and coonstripe shrimp were called "pot" shrimp because these species are usually what make up the prawn fishery in Alaska. Shrimp pots are the usual means of capturing prawns. Pink, sidestripe, and ocean pink shrimp are called "trawl" shrimp because that is how they are usually harvested.

2) These densities were segregated between those less than and greater than 190 meters in the inner and middle basins because of the difference in depth of trawls between basins.

3) Where no values were available for a group of organisms in the middle basin, inner basin values were used.

4) The density estimates were then multiplied by the estimated surface area (km^2) for each depth strata (Appendix G, Tables 9-1 and 9-2).

D. Smeaton Bay/Wilson Arm - Pandalid shrimp (pot shrimp and trawl shrimp), tanner crab, walleye pollock, rockfish, and flatfish

1) The peak average otter trawl sampling trip density from all VTN data from 1981 and 1982 (VTN 1981d, p. D-5; 1982g, p. C-35 through 60) for all groups of organisms listed above from Wilson Arm and Bakewell Arm and Smeaton Bay were used, respectively (Appendix G, Table 9-1).

2) The Wilson Arm density from 1) above was used for Smeaton Bay depths less than 190 meters. Peak average density from the trawl data in Smeaton Bay were used for depths greater than 190 meters.

3) The density estimates were then multiplied by the estimated surface area (km^2) for each depth strata (Appendix G, Tables 9-1 and 9-2).

APPENDIX G

TABLE 9-3

DETERMINATION OF MULTIPLICATION FACTOR
FOR BENTHIC ORGANISM LOSS FROM TAILINGS DISCHARGE

I. OPTION - INNER BASIN FILL NO TAILINGS PIPE MOVEMENT

A. Inner Basin

1. Average area that is actively covered by tailings in any year during the first 14 years is about one-half of the area that will ultimately be covered (Bechtel 1985a; Table 9-2); assume that 50 percent of the area affected will be affected each year between years 1 and 14 when tailings begin to spill into the middle basin. Factor to be multiplied by the biomass lost:

   MULTIPLICATION FACTOR = 0.50 x 14 years = 7.0

2. The discharge point for tailings is about the midpoint of the inner basin. Therefore, assume one half of the inner basin continues to be impacted during the remaining 43 of the 55 year life of the project.

   MULTIPLICATION FACTOR = 0.50 x 41 years = 20.5

3. Total multiplication factor for inner basin = 7.00 + 20.50 = 27.5

B. Middle Basin (inner 16 km portion)

1. The major sedimentation in the first 20 years of direct fill was recorded by Ryan (1983a, p. 82) for the lower density tailings (71.3 lbs/cu ft) to occur in the first 10-12 km from the sill downfjord. Because the main effect of increased tailing density (100 lbs/cu ft) is delay of transport over the inner sill (Ryan 1985, p. 15), assume the same behavior. Also assume the same behavior of tailings for direct fill in the middle basin or spill from inner basin. The inner portion of the middle basin is about 16 km long (Ryan 1983a, p. 77). Therefore, the portion of the area to be impacted during those years is about 12 km/16 km or 75 percent of the area. The multiplication factor then is 0.75 x 20 = 15.

TABLE 9-3 (Continued)

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2. The major area of high sediment for the period 20-60 years is the area 4-16 km from the outfall (Ryan 1983a, p. 82). This is the proportion of 8 km/16 km in the inner portion of the middle basin or 50 percent of the area. The life of the project is 55 years, with the first 14 years contained in the inner basin, leaving 41 years of fill in the middle basin. The first 20 years of fill in the middle basin are accounted for in (1) above, leaving 21 years. So the multiplication factor for this period is 0.50 x 21 = 10.5.

3. Total multiplication factor for the inner portion of the middle basin is 15 + 10.5 = 25.5.

C. Middle Basin (16 km to Kite Island)

Ryan (1985, p. 13) states after 50 years of fill, significant amounts of sediment extend to the base of Kite Island sill. The main area of tailings deposition within this outer portion of the middle basin will be from 16 to 24 km, or 8 km in length (Ryan 1983a, p. 75). The outer portion or the middle basin occupies the area 16-28 km from the inner sill (12 km length) so the area affected during the final 5 years of fill is 8 km/12 km or 67 percent. The multiplication factor for the outer portion of the inner basin is 0.67 x 5 = 3.35.

II. OPTION - DIRECT MIDDLE BASIN FILL NO DISCHARGE TO INNER BASIN

A. Inner Basin

Although some tailings will be transported into the inner basin, they were not considered significant enough to estimate a benthic loss.

B. Middle Basin (inner 16 km)

1. Use the same factor as I.B(1) above for the first 20 years, 0.75 x 20 = 15.

2. Use the same percentage as I.B(2) above, 50 percent for the remaining 35 years: 0.50 x 35 = 17.5.

3. Total middle basin (inner): 15 + 17.5 = 32.5.

C. Middle Basin (outer 16-28 km)

1. Use the same percent area as that in I C (67 percent) because the same area will be affected for 18 years instead of 5 with the fill in the inner basin first.

TABLE 9-3 (Continued)

2. The multiplication factor for the outer portion of the middle basin is 0.67 x 18 = 12.06.

III. OPTION - DISCHARGE TO SMEATON BAY/WILSON ARM

The range of bottom area that has estimated measurable sediments during a given year is 1.5 to 14 km^2 (Bechtel 1985a) and averages about 6 km^2. These areas do not include those that had slumped during any given year so they are under estimates of total area with measurable sedimentation. But some of the area that has sedimentation during a given year will have the following (1) recolonization by benthic organisms and (2) not be completely impacted. So assume the measured area is a fair representation of the area that is impacted by sediment for any given year. The average area impacted each year (6 km^2) is about one-third of the total area (16 km^2, Table 10-2) that will be covered by sediment at the end of the project. Therefore, the multiplication factor for the 55-year life of the project is 0.33 x 55 = 18.15.

IV. OPTION - INNER BASIN FILL MOVEMENT OF PIPE AFTER FOURTEEN YEARS TO MIDDLE BASIN

A. Inner Basin

1. Same as I.A(1). Multiplication factor = 0.50 x 14 years = 7.00.

2. Total multiplication factor for inner basin is 7.00.

B. Middle Basin (inner 16 km portion)

1. Same as I.B(1), multiplication factor is 0.75 x 20 = 15.

2. Same as I.B(2), multiplication factor is 0.50 x 21 = 10.5.

3. Total middle basin (inner) 15 + 10.5 = 25.5

C. Middle Basin (16 km to Kite Island sill)

1. Same as I.B(3), multiplication factor is 0.67 x 5 = 3.35.

APPENDIX G

SECTION 10

TABLE 10-1

TOTAL BOTTOM AREA AND
BOTTOM AREA AFFECTED AT END OF PROJECT
BY WATER BODY

Waterbody	Total Waterbody Bottom Area (km^2)	Bottom[a/] Area (km^2) Affected	Percent of Total Bottom Area Affected
Boca de Quadra [b/]			
Inner Basin	6.4	4.3[c/]	67
Middle Basin (Inner)	21.8	8.7[d/]	40
Middle Basin (Outer)	17.1	5.2[e/]	30
Middle Basin (Both)	38.9	13.9	36
TOTAL	45.3	18.2	40
Smeaton Bay/Wilson Arm			
Wilson Arm	8.3	4.5[f/]	54
Bakewell Arm	3.6	2.0[g/]	56
Smeaton Bay	15.1	9.8[h/]	65
TOTAL	27.0	16.3	60

a/ Values based on the most recent estimates (Ryan 1985; Findikakis 1985) of average depth of fill plus 20 meters of high turbidity layer above the fill at the end of a 55-year project. The areas are estimates of bottom area below the respective depths by basin.
b/ Values are for proposed project. Although some sediment would enter the inner basin, percent area significantly affected is assumed to be 0 if discharge was directly to middle basin, which would not increase significantly from shown estimate.
c/ Assumes effects below 60 m deep.
d/ Assumes effects to below 160 m deep.
e/ Assumes effects to below 220 m deep.
f/ Assumes effects below 75 m deep.
g/ Assumes effects below 90 m deep.
h/ Assumes effects below 115 m deep.

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APPENDIX G

SECTION 11

TABLE 11-1

ESTIMATE OF ABUNDANCE OF INNER BOCA DE QUADRA HERRING
IN SAC ROE HERRING FISHERY AT KAH SHAKES

I. ESTIMATED ABUNDANCE

A. Abundance of 1-year-old Pacific herring in inner Boca de Quadra was estimated to be 980,000 in February 1980 (Street 1980).

B. Estimated survival by age class was estimated for one British Columbia stock to be: 89 percent from age 1 to age 2 and 78 percent from age 2 to age 3 (Taylor 1964, p. 79).

C. Therefore: 980,000 age 1 herring X 0.89 = 872,200 age 2 herring; these X 0.78 = 680,316 age 3 herring.

D. Average weight of age 3 herring in British Columbia stocks equals 75 g (0.165 pound) (Taylor 1964, p. 75).

E. Estimated weight of herring from inner Boca de Quadra at age 3 is: 680,316 X 0.165 pounds = 0.112 X 10^6 pounds.

F. A large portion of the herring stocks enter the fishery off Kah Shakes at age 3 (Blankenbeckler and Larson 1982a, p. 7).

G. Average catch of herring at Kah Shakes for the three years between 1978 and 1980 averaged 1.20 X 10^6 pounds (Blankenbeckler and Larson 1982b, p. 8, 11, and 13).

H. Harvest of herring at Kah Shakes is typically 10 percent of total biomass (Blankenbecker and Larson 1982b, p. 8, 11 and 13). Therefore, total biomass average for the three years between 1978 and 1980 would be 12.0 X 10^6 pounds.

I. Estimated inner Boca de Quadra herring equal:

1. $\frac{0.112 \times 10^6 \text{ lbs}}{12.0 \times 10^6 \text{lbs}}$ = 0.93 percent of total herring biomass at Kah Shakes

2. $\frac{0.112 \times 10^6 \text{lbs}}{1.20 \times 10^6 \text{lbs}}$ = 9.3 percent of total herring harvest at Kah Shakes

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APPENDIX G
SECTION 11-2
IMPACTS TO HERRING HABITAT FROM MARINE TAILINGS DISCHARGE

This section describes three methods of estimating potential impacts to herring habitat for the four marine tailings discharge options. All three methods assume Pacific herring in Alaska may descend to 140 meters deep (Blankenbeckler 1985). The first two methods (bottom area and volume covered methods) assume bottom area or volume covered by tailings less that 140 m deep will be the impacted herring habitat. The third method (tailings plume method) assumes area of suspended sediment found to be avoided by herring, less that 140 m deep, will be the impacted herring habitat.

A. Bottom Area and Volume Covered Methods

These methods assume depth above 140 m deep, covered with tailings at the end of the 55-year project, will be the impacted herring habitat. The bottom area method assumes herring may orient to a specific bottom depth and, if that bottom depth is changed, herring habitat will be impacted because herring will not be able to descend to their desired bottom depth. The assumption is based on the knowledge that Alaskan herring descend to the bottom during the day particularly in the winter (Carlson 1980, p. 71) down to 140 m deep (Blankenbeckler 1985). The volume covered method is almost the same except it assumes that the herring will utilize the volume down to 140 m, and if this volume is occupied by tailings, it will be the impacted herring habitat.

The potential bottom area and volume for each of the four tailings discharge options are presented in Appendix G, Table 11-2. Additionally, the percent of basin volume, less than 140 m deep, covered by tailings at the end of the project is presented in Appendix G, Table 11-3. The bottom area and volume are based on the average depth of fill after 55 years of tailings discharge. The bottom area was calculated by estimating the bottom area between 140 m and the depth of fill. The volume was estimated by multiplying the average depth of fill above 140 m by the average area between 140 m and the depth of fill.

The depth of fill was determined for each of the four marine tailings discharge options by the following methods.

1. Inner Basin Discharge

   The depth of tailings fill in the inner and middle basin was based on data presented in Ryan (1985, p. 14) for inner basin discharge at the end of the 55-year project.

2. Inner Basin Discharge with Move of Pipe to Middle Basin Discharge

   Depth assumed to be the same as inner basin discharge option because it was assumed that the tailings line would be moved after the inner basin was full.

APPENDIX G
TABLE 11-2

ESTIMATED HERRING HABITAT IMPACTED BY FILL FROM BOTTOM AREA AND VOLUME COVERED BY TAILINGS

Marine Discharge Option and Basin	Average[a/] Depth (m) of Fill	Bottom Area (km^2) <140 m Deep Covered	Bottom Volume (km^3) <140 m Deep Covered
Inner Basin Discharge			
Inner Basin	80	2.1	.16
Middle Basin (Inner)[c/]	180	.2 b/	.03 b/
Middle Basin (Outer)[c/]	>240	0	0
Total		2.3	.19
Inner Move to Middle Discharge			
Inner Basin	80	2.1	.16
Middle Basin (Inner)[c/]	180	.2	.03
Middle Basin (Outer)[c/]	>240	0	0
Total		2.3	.19
Middle Basin Discharge[d/]			
Inner Basin	None	0	0
Middle Basin (Inner)[c/]	180	.2	.03
Middle Basin (Outer)[c/]	>240	0	0
Total		.2	.03
Smeaton Bay/Wilson Arm Discharge			
Wilson Arm	95	2.3	.11
Bakewell Arm	110	.7	.03
Smeaton Bay	135	.2	.04
Total		3.2	.18

a/ Depth of fill based on Ryan 1985a, p. 14 and Ryan 1983, p. 73 for Boca de Quadra and Findikakis 1985, p. 36 for Smeaton Bay/Wilson Arm.
b/ An area within the first 2 km of the inner sill less than 140 m deep will have fill depths of 20 m thick.
c/ Middle basin (inner) is area before basin starts into deepest part. This area begins about 3 km upfjord from Marten Arm extending to the inner sill. Middle basin (outer) is remaining area to Kite Island sill.
d/ Depth of fill will increase with direct middle basin discharge but the greatest increase in fill will be in the deeper part of the basin. Therefore no change in average depth of fill is indicated.

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APPENDIX G
TABLE 11-3

ESTIMATED PERCENT OF MARINE WATER (km^3) LESS THAN 140 METERS DEEP AFFECTED BY MARINE TAILINGS DISCHARGE[a/]

Marine Discharge Option and Basin	Available[b/] Volume (km^3) <140 m Deep	Volume (km^3)[c/] <140 m Deep Covered	Percent of Available Volume (km^3) Covered	Percent of Total Combined Available Volume, All Basins	Volume (km^3)[d/] Affected per Year by Tailings Plume	Percent of Available Volume (km^3) Affected per Year by Tailings Plume	Percent of Total Combined Available Volume, All Basins Affected by Tailings Plume
Inner Basin Discharge							
Inner Basin	.56	.16	29		.22	39	
Middle Basin (Inner)[e/]	2.24	.03	1		.57	25	
Middle Basin (Outer)[e/]	1.84	0	0		.48	26	
Total	4.64	.19	4	2.6	1.27	27	17.6
Inner Move to Middle Discharge							
Inner Basin	.56	.16	29		.15	27	
Middle Basin (Inner)[e/]	2.24	.03	1		.57	25	
Middle Basin (Outer)[e/]	1.84	0	0		.48	26	
Total	4.64	.19	4	2.6	1.20	26	16.6
Middle Basin Discharge							
Inner Basin	.56	0	0		.16	29	
Middle Basin (Inner)[e/]	2.24	.03	1		.77	34	
Middle Basin (Outer)[e/]	1.84	0	0		.65	35	
Total	4.64	.03	1	0.4	1.58	34	21.9
Smeaton Bay/Wilson Arm Discharge							
Wilson Arm	.67	.11	16		.14	21	
Bakewell Arm	.28	.03	11		.05	18	
Smeaton Bay	1.62	.04	2		.37	23	
Total	2.57	.18	7	2.5	.56	22	7.8
Total Combined Available Volume, All Basins	7.21						

a/ See Appendix Table G-11-2, G-11-3 and text for explanation
b/ Volume of basins between the surface and 140 m deep
c/ Volume of basin less 140 meters deep covered by tailing at the end of the project (55 year)
d/ Average region affected per year by a tailings plume (greater than 20-60 mg/l), see text for explanation
e/ Middle basin (inner) is area before basin starts into deepest part. This area begins about 3 km upfjord from Marten Arm extending to the inner sill. Middle basin (outer) is remaining area to Kite Island sill.

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3. Middle Basin Discharge

No direct fill will occur in the inner basin. Although average depth will be greater in the middle basin, most of this increase in fill will go to the deeper outer portion of the middle basin area (Ryan 1983, p. 73). Therefore, we assumed the same average depth because the increased fill will not significantly reduce the area less than 140 m deep.

4. Smeaton Bay/Wilson Arm Discharge

Depth of fill in Smeaton Bay/Wilson Arm was estimated from data in Findikakis (1985, p. 36).

B. Tailings Plume Method

This method assumes that volume of the fjords having suspended tailings concentrations greater than those estimated to be avoided by herring, will be impacted habitat. Atlantic herring have been found in laboratory studies to avoid suspended dredge spoils at concentrations of approximately 10-20 mg/l (Messieh et al. 1981; Johnson and Wildish 1981). It was assumed that end-of-the-summer models for tailings distribution for Boca de Quadra and Smeaton Bay/Wilson Arm represent the winter depth of the tailings plume (Kowalik 1984; Kowalik and Findikakis 1985; and Findikakis 1985). No models were available for winter distribution of tailings plumes so these models which represented end-of-the-summer distribution were used. The actual distribution of tailings may be quite different in the winter but should not be higher in the water column than summer distribution (Ryan 1985a, p. 19). These models predict tailings concentration as a percent of bottom concentration. It was assumed bottom concentration was 200-600 mg/l. These concentrations were used because they were found in the bottom plume of tailings at Island Copper Mine on Vancouver Island (Rescan 1983; Ryan 1985a). These concentrations may be higher than practical for the whole basin bottom as they are based on concentrations only 1 km from the outfall. The models did not predict the areal distribution of the tailings, only the two dimensional, upfjord and downfjord, distribution. It was assumed that this distribution represented the areal distribution. The depth of the tailings plume representing 10 percent of the bottom concentration (i.e., 20-60 mg/l) was considered the depth below which herring habitat would be impacted.

Unlike the previous two methods, which were based on end of the project environment, this method pertains to the period of active fill. The results are represented as average annual fjord volume affected by tailings plume. The volume affected was calculated by estimating fjord area at 140 m depth and area at the depth of the plume, averaging these two, and multiplying it by the thickness (meters) of the plume above 140 m deep.

The estimated herring habitat impacted by the tailings plume is presented in Appendix G, Table 11-4 for each of the four marine tailings discharge options. Additionally, the percent of basin volume, less than 140 m deep, affected by the tailings plume (e.g., 20-60 mg/l concentration) during active discharge is presented in Appendix G, Table 11-3. A summary of each discharge option is presented below.

1. Inner Basin Discharge with No Tailings Pipe Movement

   During the first summer of fill, the 20-60 mg/l depth (estimated to be 10 percent of the bottom plume profile) ranged from about 45-120 meters in the inner basin. Based on Figure 69 of Kowalik (1984) an average depth of 65 m was assumed. During the first summer no plume equal to 10 percent of the bottom concentration occurs in the middle basin. Because the inner basin will be completely full in 14 years this model was assumed for all 14 years. For the remainder of the project (41 years) with some exceptions, the tailings plume model for discharge to the middle basin, with the inner basin full, was assumed (Kowalik 1984, Figure 99). The depth distribution of the 10 percent level of tailings (20-60 mg/l) in the middle basin of Boca de Quadra ranged from 60 to 90 meters deep. We assumed an average of 80 meters for the middle basin for the remaining 41 years. Because this model started with the tailings plume originating in the middle basin, and not the inner basin, it was conservatively assumed that the inner basin plume was the same as during the first year of operation. Annual weighted average volume (km^3) affected by tailings in excess of 20-60 mg/l was calculated for this discharge option (Appendix G, Table 11-4).

2. Inner Basin Discharge with Move of the Pipe to Middle Basin Discharge

   The calculations and assumptions for this discharge option were the same as the inner basin discharge with the following exceptions. Because it will take approximately 14 years to completely fill the inner basin, it was assumed that the tailings line will be moved in 14 years. The model from Kowalik (1984, Figure 99) was used for both inner and middle basin for the remaining 41 years. With this model the average inner basin plume depth was assumed to be about 90 m. The resulting values are shown in Appendix G, Table 11-4.

3. Middle Basin Discharge

   Direct middle basin discharge resulted in an estimated tailings plume of 10 percent of bottom concentration ranging from 60 to 100 m, averaging about 80 m deep (Figures 60 and 99, Kowalik 1984) over the middle basin.

   The depth of the tailings plume in the inner basin varied with the model used. The model for direct middle basin discharge during the first summer estimated the inner basin 10 percent fines level at about 65 m (Kowalik 1984, Figure 60). The end of the discharge period model for the middle basin discharge (Kowalik 1984,

APPENDIX G
TABLE 11-4

ESTIMATED HERRING HABITAT IMPACTED BY TAILINGS PLUME IN THE WATER COLUMN

Discharge Option and Basin	Average Depth (m)[a/] Tailings Plume First 14 Years	Average Depth (m)[a/] Tailings Plume Last 41 Years	Volume (km^3)[b/] Affected per Year First 14 Years	Volume (km^3)[b/] Affected per Year Last 41 Years	Volume (km^3)[b/] Affected per Year Life of Project
Inner Basin Discharge[c/]					
Inner Basin	65	65	.22	.22	.22
Middle Basin (Inner)	None	80	0	.77	.57
Middle Basin (Outer)	None	80	0	.65	.48
Total			.22	1.64	1.27
Inner Move to Middle Discharge[d/]					
Inner Basin	65	90	.22	.12	.15
Middle Basin (Inner)	None	80	0	.77	.57
Middle Basin (Outer)	None	80	0	.65	.48
Total			.22	1.54	1.20

	Average Depth (m)[a/] Tailings Plume	Volume (km^3)[b/] Affected per Year
Middle Basin Discharge[e/]		
Inner Basin	80	.16
Middle Basin (Inner)	80	.77
Middle Basin (Outer)	80	.65
Total		1.58
Smeaton Bay/Wilson Arm		
Wilson Arm	85	.14
Bakewell Arm	95	.05
Smeaton Bay	100	.37
Total		.56

a/ Average depth of plume of 20-60 mg/l based on end of the summer models of Kowalik (1984, Figures 69 and 99) for Boca de Quadra discharges and Kowalik and Findikakis (1985b, Figure 23e) and Findikakis (1985b, Figure 4f) for Wilson Arm/Smeaton Bay.
b/ Volume of area less than 140 m deep.
c/ Assumed inner basin completely full after 14 years to used model for inner basin discharge for first 7 years and middle basin when inner basin full for remainder. No model available for inner basin discharge after basin is full.
d/ Assumed tailing line moved after 14 years when inner basin full. Values are same on inner basin discharge.
e/ Based on Figures 60 and 99 (Kowalik 1984) for the middle basin. It was assumed that the inner basin plume was the same, 80 m (see text for explanation).

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Figure 99) estimated the average depth at about 90 m for the inner basin, but this latter model assumes the inner basin was full, which may have affected the estimated tailings plume depth. Because we don't know what caused the difference in the inner basin 10 percent fines depth in the models (i.e., 65 m in the first, 90 m in the second) we assumed that the 10 percent depth was the same in the inner basin during both the early and end of the project fill periods (i.e., 80 meters). These models indicate that tides and currents will distribute the tailings plume by the end of the summer over both basins even with a middle basin discharge. The results are shown in Appendix G, Table 11-4.

4. Smeaton Bay/Wilson Arm Discharge

During the first summer of operation the depth of the 10 percent profile is at 90 m deep in all of Smeaton Bay/Wilson Arm (Figure 23(e), Kowalik and Findikakis 1985). By the end of the project (year 55) the fill will have altered circulation, causing the tailings plume to stay closer to the bottom and varying in depth by basin (Findikakis 1985b, Figure 4-A). Generally, the 10 percent plume ranges from about 75 to 135 m deep. In Wilson Arm the depth range was between about 75 and 95 m, Bakewell about 100 m, and in Smeaton Bay 95 to 135 m deep. The average depth of the 10 percent plume for the first year and year 55 for the Wilson Arm, Bakewell Arm, and Smeaton Bay is approximately 85, 95, and 100 m deep, respectively.

APPENDIX G

SECTION 12

TOXICITY AND BIOACCUMULATION OF TAILINGS SLURRY IN MARINE LIFE

EPA's Ocean Discharge Criteria (ODC) are specified in the Code of Federal Regulations (40 CFR 125, Subpart M) to prevent unreasonable degradation of the marine environment. "Unreasonable degradation" is defined in 40 CFR 125.121(e) as:

"(1) Significant adverse changes in ecosystem diversity, productivity, and stability of the biological community within the area of discharge and surrounding biological communities,

(2) Threat to human health through direct exposure to pollutants or through consumption of exposed aquatic organisms, or

(3) Loss of esthetic, recreational, scientific, or economic values, which is unreasonable in relation to the benefit derived from the discharge."

EPA defines 10 factors of ODC (40 CFR 125.122) that must be considered to determine unreasonable degradation:

"(1) The quantities, composition, and potential for bioaccumulation or persistence of the pollutants to be discharged;

(2) The potential transport of such pollutants by biological, physical, or chemical processes;

(3) The composition and vulnerability of the biological communities which may be exposed to such pollutants, including the presence of unique species or communities of species, the presence of species identified as endangered or threatened pursuant to the Endangered Species Act, or the presence of those species critical to the structure or function of the ecosystem, such as those important for the food chain;

(4) The importance of the receiving water area to the surrounding biological community, including the presence of spawning sites, nursery/forage areas, migratory pathways, or areas necessary for other functions or critical stages in the life cycle of an organism;

(5) The existence of special aquatic sites including, but not limited to marine sanctuaries and refuges, parks, national and historic monuments, national seashores, wilderness areas, and coral reefs;

(6) The potential impacts on human health through direct and indirect pathways;

(7) Existing or potential recreational and commercial fishing, including finfishing and shellfishing;

(8) Any applicable requirements of an approved Coastal Zone Management Plan;

(9) Such other factors relating to the effects of the discharge as may be appropriate;

(10) Marine water quality criteria developed pursuant to Section 304(a)(1)."

The toxicity and bioaccumulation of Quartz Hill mill tailings is assessed here with regard to marine life in regional fjords and to EPA's ODC.

Toxicity of Tailings:

The toxicity of mill tailings will be considered in three contexts: milling reagents, suspended solids, and dissolved metals. Each group possesses different levels and mechanisms of toxicity.

Milling Reagents

Only a provisional appraisal can be made of the hazard associated with the organic milling reagents. Additional information concerning the acute toxicity, chronic toxicity (including sublethal effects), bioaccumulation potential, and persistence of the organic milling reagents in various parts (e.g., in water and in sediments) of the aquatic environment needs to be obtained and evaluated prior to issuance of an NPDES permit.

For example, one particular milling reagent of potential concern is M-502, which belongs to a group of quarternary ammonium salts that have exhibited toxicity to a variety of freshwater organisms (Becker and Thatcher 1973, p. D.15-D.16). For example, northern squawfish (*Ptychocheilus oregonensis*) were killed between 2.5 and 6 hours following exposure to 1.0 ppm BTC-824, a quarternary ammonium compound, while chinook salmon (*Oncorhynchus tshawytscha*) exposed at the same concentration were also killed within 2.5 hr of exposure. Roccal, another member of the quarternary ammonium family, was demonstrated to be toxic to brown trout (*Salmo trutta*), with a 48-hr LC50 of 2.05 ppm (Willford 1966 as cited by Becker and Thatcher 1973). Acute toxicity was similarly demonstrated in the rainbow trout (*Salmo gairdneri*) with a 48-hr LC50 of 2.57 ppm Roccal (Willford 1966 as cited by Becker and Thatcher 1973). Unfortunately, there is no assurance that the

toxicologies of these compounds are comparable to M-502. Data on M-502's bioaccumulation potential, persistence in the environment, and other toxicological and chemical fate properties are needed to assess its hazard to aquatic life. Reagents used in the milling process are listed in Table 12-1 along with their expected concentrations in the inner basin of Boca de Quadra. The first column anticipates concentrations occurring 100 m from the outfall at a 14:1 dilution. The second is a worst case scenario predicting reagent concentrations after the inner basin fills with settled tailings piled up to the sill level (about 100 m from surface). In either case, expected concentrations of reagents do not appear to be acutely toxic to marine life, at least when exposure is brief, less than 2-4 days (the length of most of the acute toxicity tests whose results are shown in Table 12-1). This conclusion also assumes that the toxicity data (third column, Table 12-1) are applicable to organisms in Boca de Quadra.

Toxicity data are sparse for most of these reagents, particularly with respect to chronic effects. Water quality criteria for the protection of aquatic life and their uses have not been derived for these reagents. A milling reagent that seems to have the greatest toxicity potential is hydrogen sulfide in the Nokes reagent. Hydrogen sulfide is recognized as toxic primarily from studies of kraft mill liquors (Dimick 1952; Van Horn 1959), but not at concentrations expected in mill wastes from Quartz Hill. The EPA water quality criterion for hydrogen sulfide in marine waters is 0.002 mg/l (EPA 1976). A remote possibility may exist that some of these milling reagents could combine synergistically and become toxic at much lower concentrations. There is, however, no evidence that such a potential exists. While not specified as a milling reagent per se, ammonia appears in the mill tailings at potentially toxic concentrations. The source of this ammonia is unclear, but it may result from the explosives used in blasting the rock during mining. Concentrations of ammonia in the tailings range from 0.075 to 0.085 mg/l (as N) and exceed EPA's criteria for chronic toxicity of 0.02 mg/l (Table 12-2). While ammonia may dissipate rapidly as the plume mixes further into Boca de Quadra, it has the potential for both acute and chronic toxicity to marine life near the discharge.

The organic nature of most milling reagents in Table 12-1 raises the possibility of significant biochemical oxygen demand (BOD) in waters receiving mill tailings. While BOD does occur in these tailings (see Appendix F), concentrations of dissolved oxygen in the tailings slurry (>8.0 mg/l) are higher than those at depths in Boca de Quadra receiving tailings discharges (<5.0 mg/l). The BOD from these tailings will contribute slightly, but not significantly, to the reduced oxygen levels that occur naturally. Table 12-2 shows predicted oxygen concentrations at two dilutions of the tailings plume. Both are below EPA's criterion of 5.0 mg/l, but neither are significantly different from oxygen concentrations that occur naturally at these depths in Boca de Quadra (Appendix F). Therefore, other sources of BOD create an ambient condition that would not be degraded unreasonably by BOD in the milling reagents.

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TABLE 12-1

MILLING REAGENT CONCENTRATIONS WITHIN MIXING ZONES OF THE TAILINGS OF BOCA DE QUADRA DISCHARGE COMPARED TO TOXICITY DATA AVAILABLE FOR AQUATIC ORGANISMS 1/

Reagent	Concentrations in Tailings Discharge: 100 m from outfall dilution-14:1 2/ (mg/l)	Concentrations in Tailings Discharge: After inner basin is full dilution=5:1 3/ (mg/l)	Known acutely toxic Concentrations (mg/l)	References
Dowfroth 250	0.027	0.067	>100-1000	Jennett and Callier (1977)
ALFOL 6	0.40	1.003	--- 4/	
MIBC	0.784	1.960	100-1000	Jennett and Callier (1977)
Fuel oil	<0.001	0.001	0.02-6.3	Willingham et al. (1979); Anderson et al. (1974)
Stepanfloat 85L	0.098	0.246	6-7	Leclerc and Devlaminck (1952)
Sodium Silicate	0.562	1.404	247-256	Hawley (1972)
CMC-7	0.200	0.501	--- 4/	
Nokes	0.024	0.061	--- 4/	
H_2S component of Nokes	0.019	0.049	0.3-1.2	Van Horn (1959) 5/ and Dimick (1952) 5/
M502	0.887	2.218	--- 4/	
SF330	0.045	0.112	>570	Hawley (1972)
Lime	1.195	2.986	>56,000	Wallen et al. (1957)
Aerodri	0.001	0.002	10.0	MacPhee and Ruelle (1969)

1/ Data condensed from Tables 4-10 and Appendix G, Table 13-3.
2/ Diluted 2:1 in mixing box and 14:1 in mixing zone.
3/ Worst case, diluted 2:1 in mixing zone box and 5:1 in mixing zone.
4/ No data available
5/ Cited in McKee and Wolf (1971, p. 200).

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1/ Data condensed from Tables 4-10 and Appendix G, Table 13-3.
2/ Diluted 2:1 in mixing box and 14:1 in mixing zone.
3/ Worst case, diluted 2:1 in mixing zone box and 5:1 in mixing zone.
4/ No data available
5/ Cited in McKee and Wolf (1971, p. 200).

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APPENDIX G
TABLE 12-2

CHEMICAL CONCENTRATIONS FORECASTED FOR MIXING ZONES OF THE TAILINGS DISCHARGE COMPARED TO TOXICITY DATA AND WATER QUALITY CRITERIA FOR THE PROTECTION OF MARINE LIFE AND PUBLIC HEALTH FROM CONSUMPTION OF SEAFOOD

	Concentrations in Tailings Discharge 1/		Acute Toxicity 1/		Chronic Toxicity 1/		Potential Hazard in human diet 1/	Reference
	100 m from outfall dilution = 14:1	After inner basin is full dilution = 5:1 2/	Concentration	Duration	Concentration	Duration		
Dissolved oxygen	4.6	4.0	<5.0	--	<5	--	none	ADEC (1982); EPA (1976)
pH	ambient	ambient	8.5<pH<6.5	--	8.5<pH<6.5	--	--	ADEC (1982); EPA (1976)
Suspended solids	23,170 3/	46,330 4/	16,000-55,000 6/	--	35-190	--	--	Smith (1979); Campbell (1979)
Ammonia (as N)	0.085 5/	0.075 5/	0.076 5/	1 hr	0.015 5/	96 hr	--	EPA (1985)
Ag	0.16	0.39	2.3	--	--	--	50	EPA (1980)
As	1.52	1.70	69	1 hr	36	96 hr	0.175 7/	EPA (1980); EPA (1985)
Cd	0.41	0.91	43	1 hr	9.3	96 hr	--	EPA (1976); EPA (1985)
Cr	0.90	2.03	1,100	1 hr	50	96 hr	3,433,000 8/	EPA (1980); EPA (1985)
Cu	1.07	2.23	23	instantaneous	2.9	1 hr	1,000 9/	EPA (1980); EPA (1985)
Fe	0.95	0.87	1,000 10/	--	1,000	--	--	EPA (1976)
Hg	0.028	0.068	2.1	1 hr	0.025	96 hr	0.146	EPA (1980); EPA (1985)
Mn	38.53	93.33	-- 11/	--	--	--	100	EPA (1976)
Mo	41.73	90.83	>127,000 12/	--	--	--	--	Abbott (1977)
Ni	6.84	16.49	140	instantaneous	7.1	24 hr	100	EPA (1980)
Pb	2.68	6.68	140	1 hr	5.6	96 hr	--	EPA (1985)
Se	0.24	0.46	410	instantaneous	54	24 hr	--	EPA (1980)
Zn	2.20	4.75	170	instantaneous	58	24 hr	5,000 9/	EPA (1980)

1/ Concentrations expressed as mg/l, except metal cations, which are expressed as µg/l and pH.
2/ Worst case.
3/ Dilution = 8:1 for suspended solids at 100 m.
4/ Dilution = 3.5:1 for suspended solids at 50 m.
5/ Concentrations are as unionized ammonia. For ammonia in tailings, calculated unionized ammonia for a water temperature of 5°C and a pH of 8.0 for freshwater.
6/ 96-hr LC50 values for juvenile chum salmon exposed in static test with marine sediments <105 µm in diameter. For more information see Smith (1979).
7/ The 0.175 µg/l concentration is associated with a cancer risk of one additional case per 10,000 adults.
8/ Pertains to trivalent chromium only. EPA set no criterion for hexavalent chromium based solely on consumption of aquatic organisms.
9/ Level set for undesirable taste and odor quality, not human health hazard.
10/ Criteria for freshwater aquatic life. EPA has no reports for marine life.
11/ EPA (1976, 1980 and 1985) reports nothing about the toxicity of Mn to marine life, only a criteria for protection of consumers of marine mollusks.
12/ Abbott (1977) exposed single species of the hermit crab, shore crab, clam, and starfish to $NH_4 MoO_4$ for 24 or 48 hrs, then allowed 5 days for animals to recover. LC50s for all species were greater than 127 mg Mo per liter.

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Suspended Solids

Quartz Hill mill tailings contain high concentrations of suspended solids ranging between 300,000 and 400,000 mg/l. Much lower concentrations of suspended solids are known to adversely affect young fish and filter-feeding organisms. For example, juvenile chum salmon can avoid suspended solids concentrations up to 190 mg/l, but will not survive concentrations of 16,000 to 55,000 mg/l (Campbell 1979; Smith 1979). Suspended solids also irritate the feeding apparatus of filter-feeding organisms, such as copepods at concentrations as low as 50 mg/l (Sherk et al. 1976). Concentrations of suspended solids expected in the mixing zone of Boca de Quadra fall within a range known to be lethal to some species of marine life if they are exposed (Table 12-2).

Expected losses of fish from burial and high suspended sediments near the bottom are shown in Table 4-12. They are significant. These estimates of losses may be high in light of work in other fjords with tailings discharges. Waldichuk and Buchanan (1980) found measurable reductions in harvest of the commercial species of pot shrimp. Their studies were not designed to estimate losses of harvestable fish and shellfish so some losses could have occurred that were not detected.

Metals

The toxicity of dissolved metals in mill tailings is largely insignificant with respect to the Boca de Quadra discharge scenario, except for nickel. While other metal cations in these tailings are at levels below EPA criteria (Appendix G, Table 12-2), nickel exceeds the criteria at the 5:1 worst case dilution. Two other metals approach toxic thresholds in the mixing zone. Manganese in the 5:1 dilution approaches EPA's criterion of 100 μg/l for consumption of marine mollusks. Lead exceeds the chronic toxicity level of 5.6 μg/l at this worst case dilution. Molybdenum shows relatively high concentrations in both the 14:1 and 5:1 dilutions, but has low toxicity to aquatic life. The EPA has not set a water quality criterion for it.

In general, during studies done for the Quartz Hill Project, little or no leaching of metals over a 10-day observation period was observed using Quartz Hill tailings (EVS 1984a).

Silver, arsenic, chromium, mercury, and selenium showed no release from the sediments, and water concentrations remained below detection limits. Molybdenum and nickel exhibited rapid release, but ambient dissolved concentrations were not detectably increased. Metals that exhibited a slow release relative to molybdenum and nickel included cadmium, copper, iron, lead, and zinc. Metals such as copper would not be expected to desorb unless benthic conditions became acidic (i.e., pH less than 4).

Besides elevated chemical concentrations in the water column, there is a possibility of leaching or diagenesis of metals from the sediments into the interstitial water and then into the overlying water. Studies at four other mine sites (Greenex, Island Copper, AMAX/Kitsault, and Brittania Beach) were reviewed for information applicable to Quartz Hill. These studies produced a variety of results.

Studies at the Greenex lead-zinc mine, which discharges into a Greenland fjord, provide evidence of metals leaching into the water column in large quantities. These metals were in a carbonate matrix apparently favoring mobilization of lead and zinc, and toxicologically significant increases in metal concentrations in deeper parts of the fjord have been observed (Asmund 1980). Zinc concentrations, for example, reached almost 1000 μg/l at the sediment-water interface. Because the method of milling appeared to contribute to their mobilization (Asmund 1980), the relevance of this mine to Quartz Hill in terms of mobilization of metals from sediments may legitimately be questioned.

The Island Copper Mine at Rupert Inlet produces roughly half the proposed Quartz Hill discharge. Work on the leaching of metals in sediments showed that copper is released into solution at or near the sediment-water interface, and that molybdenum concentrations are higher in interstitial water than in the water column. This probably occurs as a result of dissolution of molybdenum oxides produced initially by oxidation of molybdenum sulfide during milling of the ore. Molybdenum showed a brief residence time in water, and background molybdenum concentrations are naturally high.

The report on the initial production period of the AMAX/Kitsault mine (1981) reported that no leaching of metals under normal conditions occurred in seawater, but a potential for leaching in a mild acid medium was observed in the laboratory. Although arsenic was not found in significant quantities in tailing samples from the AMAX mine, Rescan (1982) found that for arsenic the leaching potential increased with increasing pH, while the opposite held for other metals. The decrease in trace metals concentrations over time from bottom sediments is sometimes interpreted as evidence of mobilization from suspended matter into solution as metal-organic complexes. If the decrease in sediment metal concentration was due to mobilization into solution, a large and measurable increase in dissolved concentration would be expected. In most cases, this has not been found.

At the Brittania Beach copper mine on Howe Sound in southern British Columbia, augmentations in copper concentrations both interstitially and in the overlying bottom layer of water was observed, but the maximum augmentation in copper relative to control area was only 0.47 μg/l (Thompson and Paton 1978). This was of no toxicological consequence because the resulting concentration (1.2 μg/l Cu) was well below the level considered toxic to marine life.

Bioavailability of Copper in Aquatic Ecosystems

During investigations of the toxicity of tailings to marine life, particular attention has focused on the bioavailability of copper. Several environmental factors influence the toxicity of copper in receiving water environments. These must be appropriately considered in evaluating the potential ecological risk of copper residues discharged from the proposed mine. Failure to accurately assess bioavailability of copper residues may result in over- or under-estimation of the bioavailable fraction occurring in these waters.

Interstitial Water:

As a general rule, the key routes by which aquatic organisms are exposed to contaminants are through interstitial water, water at the sediment/water interface, and the water column. Neither sediment nor biological tissue generally constitute major exposure pathways for higher organisms. In defense of this assumption, Adams et al. (1985) state that the interpretation of aquatic hazard and calculation of safety factors may be based on interstitial or bottom water concentrations, which would be most reflective of the partitioning governing copper's ultimate distribution. Significantly, interstitial water concentrations are not subject to the dilution occurring in the water column and therefore are most closely representative of a "worst-case" scenario.

It is generally accepted that only those metals that are soluble in interstitial water appear to be available for uptake to deposit-feeding infauna such as certain polychaete worms. It is also noted that no extraction procedure effectively predicts the availability of heavy metals to benthic infauna. This substantiates the use of interstitial water concentrations as the best indicator of bioavailable copper.

Total Recoverable Fraction:

The EPA assumes that the "total recoverable" fraction, which requires an acidification step, is most representative of conditions occurring in situ. In fact, rather than the pH of 2 created by this acidification, benthic pH levels in receiving water fjords are expected to exceed 7. The unrealistically low pH thus created in the laboratory strips copper residues from both dissolved and particulate complexing agents. It is noted that were this condition of low pH to actually occur, it alone would cause widespread mortality; this and other effects precipitated by the pH would probably supersede any effects caused by the copper itself. Garrels and Christ (1964) report a copper solubility in fresh water of 64 μg/l at a pH of 7, while for a pH of 8 this solubility is expected to drop an order of magnitude to 6.4 μg/l (Hem 1970). This is far below the concentration of at least 40 mg/l assumed by the EPA in calculating the bioavailable fraction.

General Complexing Agents:

It is well documented that copper's bioavailability and, consequently, toxicity, is closely related to the concentrations of inorganic and organic ligands in the soluble phase (e.g., Newell and Sanders 1986) and the affinity for copper of metal-binding sites in the particulate phase (O'Donnel et al. 1985). Concentrations of both dissolved and particulate complexing agents must be determined on a site-specific basis (not normally practical) because of the complex and variable behavior of copper with these complexing agents. In the case of Boca de Quadra and Smeaton Bay, suspended solids are expected to be high, which should increase the binding capacity of copper and reduce its bioavailability. In the absence of such data, toxicity testing would be desirable because it would provide actual experimental evidence regarding the bioavailability of copper residues.

The cupric ion is highly reactive, forming complexes with inorganic and organic ligands as well as binding to suspended solids (Wagemann and Barica 1979). Partitioning and complexation can reduce the total dissolved copper that is bioavailable (EPA 1985; O'Donnel et al. 1985). Bound or complexed copper is very stable and tends to remain in this state. Metals released into aquatic ecosystems normally exist almost entirely in complexed forms or bound to particulates, with the concentrations of bound or complexed metal being orders of magnitude higher than the concentration of the dissolved, uncomplexed metallic ion (Luoma 1985; Stiff 1971). The pH of the fjords (7.9-8.1) favors complexed or particulate bound forms of copper, forms which are generally not bioavailable (Poling 1982).

Dissolved Complexing Agents:

Dissolved complexing agents, such as humic and fulvic acids, may also be important in affecting the bioavailabilty of copper. For example, Oakley et al. (1981) showed that the affinity of copper was high for humic acid relative to other phases, and Newell and Sanders (1986) showed that binding capacity is directly proportional to dissolved organic carbon (DOC) concentrations. Harrison (1982, 1985) investigated the effects of various dissolved chelating and complexing agents on oyster embryo chronic toxicity, and found that humic acid reduced larval abnormalities from 43 percent to 2.3 percent when they were exposed to 10 μg/l copper concentrations. At 60 μg/l exposures, EDTA, a copper chelating agent, reduced abnormalities from 100 percent to 2.4 percent. Field verification for this is provided through the work of Chapman et al. (1979 as cited by Lewis and Cave 1982), where juxtaposed to sediments containing up to 14 percent copper was a "healthy and diverse community of organisms living on and around the pilings." Later tests with coho smolts and marine crabs suggested that the copper was not in a biologically available state and thus produced no toxicity.

The tailings proposed for discharge into the fjords are known to have substantial copper concentrations, but in order to understand the potential for toxicity as a result of this discharge, measurements should be made on-site in order to determine actual dissolved

concentrations in fjord receiving waters. Bioassays would be a satisfactory alternative; relative measurement of copper (dissolved) vs. copper (total recoverable) would be strongly suggested.

Copper Speciation:

As suspended particulates are expected to be high in receiving waters following tailings discharge, sorption of copper to these particulates is expected to be substantial. However, analytical detection of total copper often has little to do with distribution of forms (i.e., chemical species) or concentrations in living tissues. Ayling (1974) and others have found that copper concentrations in oyster tissue did not necessarily coincide with distributions of copper in surrounding sediments, which lends support to the all-important assertion that the degree of uptake by living organisms is directly related to the form and phase (i.e., species) of copper present.

In conclusion, the use of acid-extractable copper concentrations as a measure of the biologically available fraction is overly conservative. It appears to greatly overestimate copper's bioavailability by failing to account for the pH of seawater, as well as its buffering tendencies. In addition, dissolved metals are normally precipitated with complexing agents, which reduces or precludes their bioavailability. Thus the probabilities of water quality criteria exceedances as shown in the EPA risk assessment probably are not reflective of the scenarios expected to occur _in situ_.

Tailings Toxicity

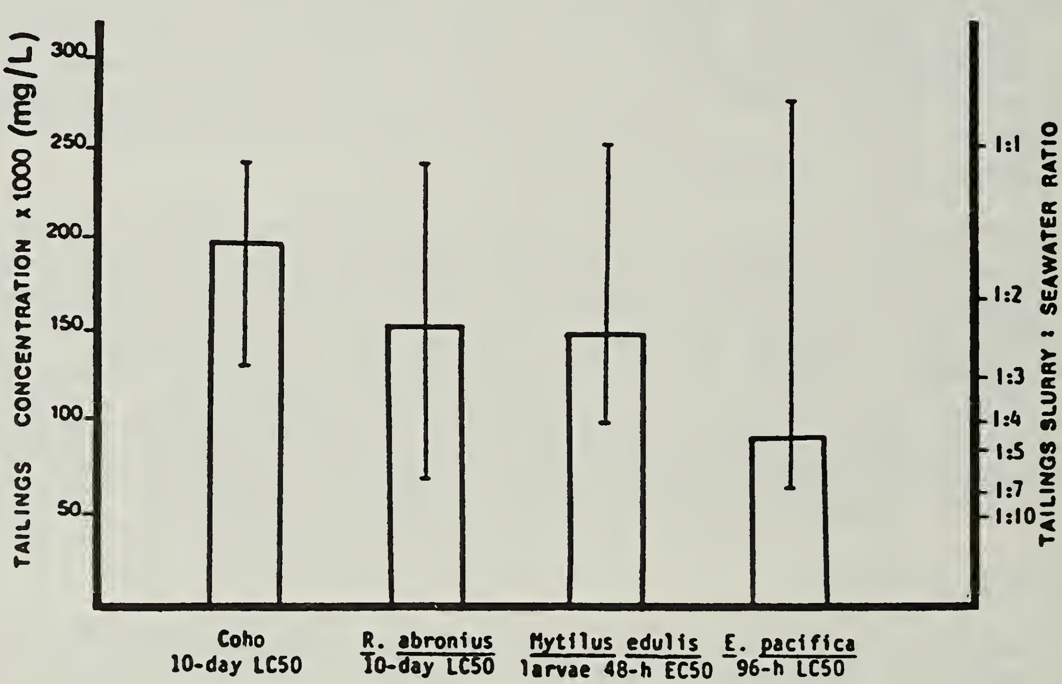
EVS Consultants (1984a, 1984b) assessed the acute and chronic toxicity of samples of Quartz Hill tailings to several species of marine life. Their studies indicated that the tailings samples had low toxicity, but their studies had several methodological flaws that made it impossible to reach definitive conclusions concerning hazard. The most important flaw was that the concentration of tailings added to the test containers was much higher than the concentration to which the test organisms were exposed. This was due to reliance on test conditions that allowed the tailings to settle out over time. The result is that higher concentrations than actually existed were reported as being toxic. Control mortalities that sometimes were too high and omission of information concerning the organic milling reagents are other deficiencies.

Acute Toxicity:

Prototypic Quartz Hill tailings produced by the pilot plant in October 1983 were used in acute toxicity tests utilizing juvenile coho salmon (_Oncorhynchus kisutch_), amphipods (_Euphausia pacifica_), and bay mussel larvae (_Mytilus edulis_). With the exception of the coho salmon bioassay, in which water replacement rates were greater than 0.5 l/g fish/day, all other tests were conducted under static conditions. Tailings were allowed to settle rather than kept in suspension over the course of the tests. Results indicated low acute toxicity to these species. The results are summarized in Figure 12-1.

SUMMARY OF
BIOASSAY RESULTS, ACUTE LETHALITY AND 95% CONFIDENCE LIMITS

QUARTZ HILL MINE TAILINGS



EVS CONSULTANTS (1984) BIOASSAY RESULTS USING SEAWATER DILUTIONS OF QUARTZ HILL MILL TAILINGS AND FOUR MARINE SPECIES :

- JUVENILE COHO SALMON (*Oncorhynchus kisutch*)
- AMPHIPODS (*Rhepoxynius abronius*)
- MUSSEL LARVAE (*Mytilus edulis*)
- ZOOPLANKTON (*Euphausia pacifica*)

U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE QUARTZ HILL MOLYBDENUM PROJECT MINE DEVELOPMENT EIS	FIGURE 12-1
QUARTZ HILL MINE TAILINGS	envirosphere company A Division of EBASCO SERVICES INCORPORATED
SOURCE EVS DATE 1984	

Although the results from the lethality tests indicate a low order of toxicity, reported values may not actually reflect the tailing's inherent toxicity. Bioassays utilizing mussel larvae and juvenile coho salmon were conducted in test vessels containing up to 240,000 mg/l of tailings. Because tailings naturally settle out of the water column with time, test organisms could only be exposed briefly to the reported suspended solids concentrations. Given the exposure condition tested, it would have been more appropriate to have reported the concentrations of total recoverable metals, milling reagents (which were not studied), and suspended solids in the test and control supernatants. Therefore, the concentrations reported as being toxic appear inaccurate.

For instance, in the salmon bioassay, mortality was observed only at the highest concentration (240,000 mg/l). These individuals all died on the first day of the study. Suspended solids measurements (for coho only) taken that day indicated a concentration of 2,543 mg/l in the supernatant. If mortality was due to suspended solids, then a 24-hr LC50 could be as low as 2,543 mg/l. Additionally, the presence or absence of suspended solids in the water column would likely affect amounts of dissolved constituents by either decreasing or increasing their concentration.

Another example is the acute toxicity tests with mussel larvae conducted using the second batch of tailings at concentrations ranging to a maximum of 250,000 mg/l. Results indicated a low order of toxicity to these organisms; however, due to settling of suspended solids within the 48-hr period, initial concentrations and exposure concentrations are quite different. Therefore, 48-hr EC50 values most likely do not accurately represent exposure.

Toxicity tests conducted by EVS Consultants (1984a) showed that mill tailings were acutely toxic to selected marine organisms at slurry to seawater ratios of <1:7. This indicates that the worst case dilution of 5:1 (Table 12-2), occurring after the inner basin of Boca de Quadra is full, would cause mortalities to marine organisms that did not or could not escape the discharge plume. Whether or not the toxic agents were metals like copper and nickel, ammonia, or suspended solids, or a combination of these is unclear.

EVS Consultants (1984b) studied the effects of Quartz Hill pilot plant tailings on the development and growth of Dungeness crab larvae, the burrowing behavior of the clam (<u>Macoma balthica</u>), and growth in the phytoplankton <u>Dunaliella tertiolecta</u>. However, high mortality rates of crab zoea observed within the first 7 days of the 30-day regime in both treatment and control groups precluded any definitive data interpretation.

Clams used in burrowing studies were kept in control sediment or containers with 4 cm of control sediment layered with 1 cm of tailings. Metabolic waste buildup in the tanks following one month of testing necessitated adjusting the rate of water replenishment from 1 to 1.5 tank volumes per day. The median effective time for burrowing (ET50) was observed at intervals of 0, 1, 2, 3, 4, 6, 12, and 16 weeks for each of four possible treatments: control-reared clams reburying

in clean sediments or tailings, and tailings-reared clams reburying in clean sediments or tailings. During the first week, slow reburial times were observed for control-reared clams in both sediments, and these may have been attributable to pretest holding procedures (EVS Consultants 1984b, p. 38). The clams were held in seawater trays lacking sediment for a period of 48 to 96 hrs prior to their exposure to sediment or tailings. Clams reared in tailings generally took longer to rebury than control clams (EVS Consultants 1984b, p. 39).

Sublethal toxicity bioassays with phytoplankton were conducted to monitor growth in control treatments and test concentrations, which ranged from 1 to 10,000 mg/l tailings. Test chambers containing the cell cultures were shaken once daily by hand. Consequently, tailings were transiently suspended once per day. Reported concentrations do not accurately represent exposure in the supernatant. Growth of cells at 10,000 mg/l of tailings was inhibited initially; however, by the conclusion of the 13-day incubation period, this same treatment group showed significantly higher cell density than both control and other test concentrations (EVS Consultants 1984b, p. 40).

Feeding activity and respiration in zooplankton exposed to sublethal concentrations of tailings from the Kitsault, British Columbia, mine have been studied by Anderson and Mackas (In Press). Respiration was measured during 24-hr exposures to tailings concentrations ranging from 0 to 980 mg/l. Oxygen consumption tended to increase at concentrations less than 40 mg/l, but decreased at higher concentrations (200 mg/l) during 24 hours in some of the tests. Responses at similar concentrations were obtained in the feeding studies. The feeding studies documented that zooplankton would consume and excrete tailings. Fecal material was also observed to contain tailings in addition to algal fragments.

Chronic Toxicity:

The data are not adequate to definitively assess the sublethal and chronic effects that could arise from exposure to the various constituents contained in Quartz Hill mine tailings. In general, findings from the Kitsault mine confirmed the suspicion that physical factors such as burial under tailings are the most important in determining deleterious effects to marine biota. This is also confirmed by the U.S. Army Corps of Engineers (1975), which found that very little solids deposition could have a stronger impact than suspended solids. Goyette and Nelson (1977), however, stressed that the mine has not been in operation long enough to allow all deleterious impacts to fully develop. In an update on the Island Copper mine program, Evans et al. (1979) presented some conclusions regarding long-term impacts. They noted that the discharge after 7 years has proven environmentally acceptable, with their success ascribed to the following: (1) control of pH and use of biodegradable flocculants and coagulants, (2) premixing of seawater and avoidance of air entrainment, and (3) a deep fjord discharge. These findings and those of other operations may be used only with qualification and may not be considered definitive, because differences with Quartz Hill in terms of fjord hydrography and tailings composition/behavior may be significant.

Bioaccumulation of Tailings:

This section addresses bioaccumulation and biomagnification of the metal in tailings. The bioaccumulation assessments performed to date have not evaluated the hazards associated with many of the milling reagents. Such an assessment is necessary. A first-tier hazard assessment[1/] of these compounds (ASTM 1985a, p. 618) can be made by obtaining octanol-water partition coefficients for each compound and predicting bioconcentration factors for aquatic life using published equations (Kenaga and Goring 1980, p. 90). None of the reagents specified in Table 12-1 are expected to accumulate along biological pathways to hazardous proportions, but sufficient information is not available to assess this potential.

Almost all the metals can be taken up by marine life via both the surface membranes (i.e., gills, skin) and diet (e.g., see residue data in EPA 1980b, c, d, and f). Uptake is usually greater in invertebrates than fish, and most of the organism's body burden of metal is stored in metallothionein pools where it is conjugated and not biologically available (e.g., see Dixon and Sprague 1981; Brown and Thompson In Press). Transfer of the organisms to uncontaminated water results in loss or depuration of the metals, leaving little or none of the persistent residue that typifies organic mercury and certain polychlorinated hydrocarbons (EPA 1980d, f, g). Therefore, the hazard associated with most of the inorganic phases of the metals appears low. An exception is arsenic, which is a carcinogen in humans (EPA 1980h) and taken up and converted to organic forms in marine biota (Eisler 1981). The organic forms are lipid soluble and are stored in the fat where they can accumulate. Eisler (1981) contends that the organic arsenic residues in marine life are probably less hazardous to people than the inorganic compounds. The latter are much more toxic to people. Fortunately, no apparent hazard to upper trophic levels (e.g., eagles, seals, humans) is expected from consumption of arsenic-contaminated fish or shellfish because arsenic concentrations within (0.002 mg/l) and beyond (0.0015 mg/l) the mixing zone are well below the concentration (0.175 mg/l) producing hazardous body burdens in fish and shellfish (Appendix G, Table 12-2). Studies by EVS Consultants (1984b) demonstrated only low level accumulation of metals

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1/ It should be possible to perform the first phase of the hazard assessment (ASTM 1985a, p. 618) with the following information:

- o Acute toxicity - 96-hr LC50 for a sensitive fish or invertebrate (does not need to be indigenous).
- o Bioaccumulation potential - octanol-water partition coefficient.
- o Persistence - half-life in water containing a diverse microbial flora.

from Quartz Hill tailings. With the exception of slightly elevated levels of manganese in mussel tissue, no test organisms exhibited metals concentrations that exceeded those in the tissues of control animals. Metal concentrations of the sediment in the treatment groups were 3 times higher for copper, 5 times higher for lead, and 60 times higher for molybdenum than the control sediment. Metal concentrations in the overlying water of the treatment tanks indicated leaching, with manganese 20 times higher and molybdenum 60 times higher than the control.

The EVS Consultants (1984b) study investigated the bioaccumulation potential of selected metals--cadmium, copper, manganese, molybdenum, lead, and iron--from Quartz Hill mill tailings. Dungeness crabs, clams (*Macoma balthica*), bay mussels, and sand dabs (*Citharicthys stigmaeus*) were exposed to tailings over a 4-month period and analyzed periodically for residues of the heavy metals in the tissues. The concentration of tailings used initially in each static renewal test was a 4:1 dilution of tailings with clean sediments. This was accomplished by filling test chambers (separate for all except clams and mussels) with 4 cm of clean marine sediments and covering them with a 1 cm layer of tailings. Increased levels of biologic waste products necessitated increasing the water replacement rate from 1 to 1.5 tank volumes per day (3 tank volumes per day in the crab and sand dab tests). The supernatant water overlying the control and test sediments/tailings was sampled concurrently with organisms at 0, 1, 2, 3, and 4 months. Control and test sediments were sampled at 0, 1, and 4 months.

Results from other tests of mine tailings presented previously also indicate that metals, such as cadmium, zinc, lead, and copper do bioaccumulate modestly where tailings contained elevated concentrations of these metals. McGreer et al. (1980) studied bioaccumulation in the mussel *Mytilus edulis* and the clam *Macoma balthica* exposed to tailings from three mine sites: 1) the Island Copper mine at Rupert Inlet, Port Hardy, British Columbia, 2) the Nanisivik mine on Stathcona Sound, Baffin Island, Northwest Territory, and 3) the Greenex mine on Agfardlikavsa Fjord, Marmorilik, Greenland. The Nanisivik mine produced ores of copper, lead, iron, cadmium, and zinc. The Greenex mine produced ores of copper, lead, cadmium, and zinc. And the Island Copper mine produces only ores of copper. Their results show that all test metals could bioaccumulate in mollusks whenever tailings contained elevated concentrations of these metals. Bioaccumulation, therefore, was largely a function of metal availability. These findings are supported by a similar study of tailings from the AMAX/Kitsault mine located less than 50 miles from the Quartz Hill site on the Alice Arm of Observatory Inlet in British Columbia (Goyette and Christie 1982b). This was a molybdenum mine, and thus even more relevant to this Quartz Hill assessment. Tests conducted within a relatively short period after startup showed that some marine bivalve samples (*Yoldia thraciaeformis*) had accumulated copper, lead, cadmium, and zinc in their soft tissues.

In assessing the potential for bioaccumulation and biomagnification of metals in Quartz Hill tailings, the findings discussed above suggest that marine bivalves may accumulate cadmium, copper, iron, lead, and zinc to levels that are greater than respective concentrations in sediment-tailings mixtures. No evidence is offered, however, suggesting that biomagnification processes are active for these metals. Since these metals are not known to undergo food chain magnification in marine organisms in a way similar to that of mercury, biomagnification of metals in Quartz Hill tailings is not considered a significant issue. But bioaccumulation remains a potential problem where bivalves are concerned. Quartz Hill tailings contain elevated concentrations of these metals (see Table 4-6), although they are not as high as those studied by McGreer et al. (1980). Nevertheless, Goyette and Christie (1982b) have shown that operations of a nearby molybdenum mine on Alice Arm may increase the accumulation of copper, lead, cadmium, and zinc in one species of clam. Perhaps of greater significance is the absence of bioaccumulation of these metals by other marine animals for which tissue concentrations were analyzed by Goyette and Christie. These organisms included species of another clam, a mussel, three crabs, six shrimp, and five bottom fishes.

Suspended Solids:

Although some marine organism mortalities may occur from toxic levels, effects from the high suspended sediment near the bottom and high deposition rate will be the major source of impacts. Where levels may be toxic, high settling rate would have already buried benthic organisms, resulting in losses of demersal organisms in the area. These losses have already been accounted for in Table 4-12. Some mesopelagic organisms may be affected by toxic levels, but this would be confined to a small area. Some important, vertically migrating food chain organisms such as euphausiids, which are an important food item for herring and walleye pollock, could be affected. These organisms are important even in the epipelagic area. Although some may be found near deep areas, the highest abundance is in the 30-50 m depth range (VTN 1982h, p. 65). Therefore, a minor loss of these organisms may occur in close proximity to the tailings plume, but the overall loss would be small and have no significant effects on marine fish. Zooplankton that vertically migrate and have ingested or are carrying suspended sediment particles may be ingested by epipelagic organisms (e.g., herring, salmon), possibly resulting in bioaccumulation of heavy metals in these fish. In general, however, studies at other mines (see previous discussion) suggest that effects of bioaccumulation will be insignificant.

In summary, the existing information suggests that tailings from the proposed Quartz Hill facility will possess a low acute toxicity to marine organisms larger than plankton. Plankton, which cannot readily avoid the plume of tailings, are most vunerable to the suspended solids, ammonia, and other toxicants in the plume. Moreover, metals in the tailings do not appear to be bioaccumulated to the extent known to be inimical to other marine organisms, wildlife, and public health.

There are, however, some important gaps in information that should be addressed as part of an NPDES permit. More definitive information is needed concerning the chronic toxicity of the tailings, particularly effects on reproduction, and on the bioaccumulation potential of the organic milling reagents.

APPENDIX G

SECTION 13

PROBABILITY AND POTENTIAL BIOLOGICAL EFFECTS OF CHEMICAL AND OIL SPILLS INTO PROJECT STREAMS

Spills from Truck Hauling

The chemicals that would be hauled from the wharf on Wilson Arm to facilities at the mine, mine service area, or Tunnel Creek are identified in Appendix G, Table 13-1, along with information on how much material could be spilled and the probability of a spill. The amounts that could be spilled are large (e.g., 5,500 gallons) because large amounts are scheduled to be hauled on each truck. The probability of a major accident involving nonfuel chemicals only is low for a mill site at Tunnel Creek, 0.31 accidents[1/] for the 55-year project life. For a mill site at Beaver Creek, and one at North Meadow, accidents during the project increase to 1.46 and 1.53, respectively. The probability of a major accident involving fuel is moderate: 1.29 accidents for the project life with the Blossom access route, 1.36 accidents for the Keta access route, and 0.20 for the Tunnel access route. The probability of any particular chemical entering the stream is lower. Chemicals hauled as solids rather than liquids would have an even lower probability of entering project area streams because they would have to be dumped directly into a tributary, rather than flow into it, in order to reach the larger streams quickly, before containment or cleanup could be effected.

The amount of chemical entering the stream would likely be only a fraction of that spilled because the probability of a total rupture versus a leak is low. Implementation of a rapid and effective program of spill containment and cleanup would minimize the amounts of chemicals entering project streams.

Based upon a scenario where half the chemical in a truckload is spilled into the streams or their tributaries, extremely high concentrations could occur for a short time, depending upon the characteristics of the spill (Appendix G, Table 13-2). These concentrations would be the same for a spill of the complete load because the length of time required for the spill to occur would be twice as long, and the volume impacted would be twice as large. Because the calculations assume that the spill travels as a pulse ("plug" flow) down the stream, the entire stream length would be subjected to these concentrations. Therefore, the relative size of the "plug" would not change the impacts attributed to these concentrations. If these concentrations were to occur, high mortalities of all forms of aquatic life, including waterfowl and other wildlife, could result from the pulse of chemical traveling downstream. This conclusion is based upon a comparison of expected

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1/ Fractional accidents result from ratioing number of accidents per million miles driven.

APPENDIX G

TABLE 13-1

ESTIMATES OF THE POTENTIAL FOR A SPILL OF MILLING REAGENTS INTO PROJECT STREAMS

AMOUNTS OF MILLING REAGENTS THAT WILL BE HAULED FROM WHARF TO ORE PROCESSING FACILITY 1/

Chemical	Amount/ Container	Containers/ Year	Estimated Containers/ Trip	Total Trips/ Year
Dowfroth	5,500 gal	2	1	2
Stepanfloat	5,500 gal	7	1	7
MIBC	5,500 gal	70	1	70
Lime	1,500 lb bags/10 bags per sea container	261 sea container	3	87
Sodium Silicate	5,500 gal	40	1	40
Nokes Reagent	1,425 lb bin	1,107	6	185
ALFOL	5,500 gal	35	1	35
CMC	1,500 lb bags/10 bags per sea container	88 sea container	3	30
M502	5500 gal	124	1	124
SF 330	140 lb drums	2,086	15	139
			TOTAL	719

1/ Sheflott (1983 and 1984).

A. Estimating Aerodri

1. Aerodri use 16 lb/day, shipped in 55 gal drums

2. Aerodri 16 lb/day x 91 days x $\frac{1\ \text{gal}}{6.73\ \text{lb}}$ x $\frac{1\ \text{drum}}{55\ \text{gal}}$ = 3.9 therefore 4 drums every 3 months. It is assumed that the Aerodri will be trucked with other chemicals and would result in at most one additional trip per year.

B. Chlorine - previously estimated (11/8/83) as 2-3, 150-lb cylinders every 3 weeks for sewage treatment plus 100 lbs every 2 weeks for process requirements.

Assume 4, 150-lb cylinders every 3 weeks

17 trips/year

0822K

C. NH_4NO_3 - cited as 46,000 lbs/day (project description). Also given as 124 x 10^6 lbs/yr (G. Shefflot 1983a) with 20 tons/trip for 320 days/yr.

Assume maximum - 46,000 lbs/day at 365 days/yr.

= 2 trips/day for 365 days = 730 trips

D. Road Accident Statistics (Purves 1983)

1. Based on Big Salt Road (Hollis-Kalwock - S.E. Alaska) - Section analyzed is 20 ft wide, 30 MPH maximum design, unpaved, used as haul road.

2. 17 accidents in 4-1/2 years = 1.9313 accidents/million miles.

3. Project accidents for chemical spill, excluding fuel oil (to be done separately):

   Total trips/yr = containers/yr = 1467 (730 NH_3NO_2 + 720 milling reagents + 17 chlorine).

   Road lengths (bulk sampling EIS, scaled map)
   Blossom 9-1/2 miles
   Keta 10 miles
   Tunnel Creek 2 miles

4. Therefore:

   <u>Blossom</u>

   1,467 trips/yr x 9.5 mi/trip = 13,936.5 mi/yr x 55 yrs (project life) = 766,508 mi.

5. Keta 1,467 x 10 = 14,670 x 55 = 806,850 mi.

6. Tunnel 1,467 x 2 = 2,934 x 55 = 161,370 mi.

   Apply accident stats: <u>chemical spills only</u> - excludes fuel oil

   766,508 x $\frac{1.9313 \text{ accidents}}{10^6 \text{ mi}}$ = 1.46 accidents/project Blossom Rd.

   806,850 x $\frac{1.9313 \text{ accidents}}{10^6 \text{ mi}}$ = 1.53 accidents/project Keta Rd.

   161,370 x $\frac{1.9313 \text{ accidents}}{10^6 \text{ mi}}$ = 0.31 accidents/project Tunnel Rd.

7. For a spill (excluding fuel) the likelihood of it being a particular component (on a trip basis) is as follows:

	Percent chance
NH_3NO_2	49.76
Dowfroth	0.14
Stepanfloat	0.48
Methyl Isobutyl Carbinol	4.78
Lime	5.93
Sodium Silicate	2.73
Nokes Reagent	12.61
Aerodri	0.07
SF 330	9.47
Chlorine	1.16
ALFOL	2.38
CMC-7	2.04
M502	8.45

8. Fuel Oil - source U.S. Borax (1984c) (No. 2 type fuel oil will not be carried by tanker truck)

Fuel transported by tanker truck:

11.3×10^6 gal/year diesel
0.22×10^6 gal/year gasoline

using 9,000 gal tanker truck

$= 11.3 \times 10^6 \text{ gal/yr} \times \frac{1 \text{ trip}}{9000 \text{ gals}} = 1{,}256$ trips/yr of diesel

$0.22 \times 10^6 \text{ gal/yr} \times \frac{1 \text{ trip}}{9000 \text{ gals}} = 25$ trips/yr gas

total trips = 1,281

1,281 x 9.5 x 55 = 669,322 mi/project life, Blossom
1,281 x 10 x 55 = 704,550 mi/project life, Keta
1,281 x 2 x 55 = 140,910 mi/project life, Tunnel

$669{,}322 \text{ mi} \times \frac{1.9313 \text{ accidents}}{10^6 \text{ mi.}} = 1.29$ accidents/project, Blossom

$704{,}550 \text{ mi} \times \frac{1.9313 \text{ accidents}}{10^6 \text{ mi.}} = 1.36$ accidents/project, Keta

$104{,}910 \text{ mi} \times \frac{1.9313 \text{ accidents}}{10^6 \text{ mi.}} = 0.20$ accidents/project, Tunnel

TABLE 13-2

EXPECTED CONCENTRATIONS OF MILLING REAGENTS SHOULD HALF THE AMOUNT HAULED BY A TRUCK BE SPILLED AND ENTER THE STREAMS IDENTIFIED
(all concentrations g/l)

Parameter	Blossom River Conc. g/l	Blossom River Length, ft.	Blossom River Duration, min.	Beaver Creek Conc. g/l	Beaver Creek Length, ft.	Beaver Creek Duration, min.	Keta River Conc. g/l	Keta River Length, ft.	Keta River Duration, min.	Tunnel Creek Conc. g/l	Tunnel Creek Length, ft.	Tunnel Creek Duration, min.	Beaver Cr. into Blossom River Conc. g/l	Beaver Cr. into Blossom River Length, ft.	Beaver Cr. into Blossom River Duration, min.
Ammonium Nitrate	15.4	200	2	404.5	150	4	8.4	193	2	24.6	244	2	1.53	2000	20
Dowfroth 250	30.7	200	2	1594.9	75	2	16.4	193	2	48.2	244	2	3.0	2000	20
Stepanfloat	25.3	200	2	1311.9	75	2	13.5	193	2	39.7	244	2	2.5	2000	20
MIBC	25.3	200	2	1311.9	75	2	13.5	193	2	39.7	244	2	2.5	2000	20
Sodium Silicate	52.4	200	2	2721.3	75	2	28.0	193	2	82.3	244	2	5.1	2000	20
SF 330	1.4	200	2	74.7	75	2	0.8	193	2	2.2	244	2	0.1	2000	20
Lime	30.7	200	2	1594.9	75	2	16.4	193	2	48.2	244	2	3.0	2000	20
Aerodri	1.01	200	2	52.5	75	2	0.5	193	2	1.6	244	2	0.1	2000	20
CMC-7	30.7	200	2	1594.9	75	2	16.4	193	2	48.8	244	2	3.0	2000	20
Nokes b/	5.8	200	2	303.0	75	2	3.1	193	2	9.2	244	2	0.6	2000	20
ALFOL	25.8	200	2	1337.2	75	2	13.8	193	2	40.4	244	2	18.9	2000	20
M502	1.4	200	2	74.7	75	2	0.8	193	2	2.2	244	2	0.1	2000	20
Chlorine	0.41	200	2	21.3	75	2	0.2	193	2	0.6	244	2	0.4	2000	20
Diesel	39.4	200	2	2041.5	75	2	21.0	193	2	61.7	244	2	38.7	2000	20
Gas	39.4	200	2	2041.5	75	2	21.0	193	2	61.7	244	2	38.7	2000	20

a/ Calculations are based upon data supplied by U.S. Borax (Shefflot 1983 and 1984) (Appendix G, Table 13-1). The chemical was assumed to enter the stream in a single dose. There is a linear relationship between exposure concentration and length affected. Concentrations represent maximum values, while duration and length are based on stream morphology (width, depth, and velocity). As a first approximation, plug flow was assumed; i.e., a body of water of given length and concentration will flow as a plug downstream, appearing at any fixed point for the duration given. Should an entire truck load be spilled, the duration of the concentration at a fixed point would be twice as long.

b/ Nokes reagent is a mixture of NaOH and P_2S_5. These reagents are mixed together in approximately equal weights. Therefore, it is assumed that equal weights would be contained in a given shipment. The concentration of the individual components would be half of the concentratioins shown.

1061K

chemical concentrations for the worst case scenario (Appendix G, Table 13-1) with the limited available aquatic toxicity data (Appendix G, Table 13-3). This data base needs to be expanded because most periods in which the fish and invertebrates were exposed to the chemicals were longer than those characterizing spill conditions. For example, effective spill containment and cleanup should limit exposure of aquatic life to acutely toxic concentrations to a few hours, but most of the toxicity data pertain to exposures longer than 48 hours. Although concentrations killing aquatic life in a few hours would be higher than those shown in Appendix G, Table 13-3, they would still be below those forecast for a worst case spill. Toxicity data for wildlife are even more meager, but it is known that spills of oil and immiscible substances (e.g., carbinol) could exert a physical effect.

Oil Pipeline Rupture

When full, the 1,000-ft pipeline extending from the wharf to the tank farm would contain 9,880 liters of diesel oil, and the 7,000-ft length of pipe running from the tank farm to the power plant would contain 69,180 liters.

According to U.S. Borax (Sheflott 1983b), there would be a berm equipped with a liner around the tanks (and presumably the pumping station) that is large enough to accommodate the pipeline's volume of oil should a rupture occur at the pumping station. A rupture along the length of either pipeline could exhaust whatever oil existed upstream. However, backflow preventers installed in these pipelines would keep upstream oil from spilling into aquatic and terrestrial habitats in the event of a pipeline rupture.

A thorough analysis of probabilities of spills from pipeline breaks has not been prepared, but data concerning spills of crude and petroleum products from pipelines in Washington suggest an extremely low probability, mainly because (1) the pipeline's length is so short and (2) it will be built with schedule 80 carbon steel, twice the normal thickness (Sheflott 1983b). For example, in the greater Puget Sound area, there are approximately 240 miles of petroleum pipeline capable of carrying 400,000 barrels (63,592,000 liters) per day, and the probabilities of spills are as follows (Oceanographic Institute of Washington 1980):

Spill Magnitude (gal)	Probable Spill Frequency in Washington. Once Every:
100-420	11 yr
420-4,200	9.4 yr
4,200-42,000	26 yr

TABLE 13-3

TOXICITIES TO AQUATIC LIFE OF MILLING REAGENTS, FUELS, AND OTHER CHEMICALS PROPOSED FOR USE AT QUARTZ HILL MINE

Substance	Species Tested	Type of Test Or Response Measured	Toxic Conc., mg/l	Reference
SF 330 (polyacrylamide flocculant	Fathead minnow	Acute	>570 w/v	Hawley (1972)
Aerodri[d]	Chinook salmon and Coho salmon	Death in 3-7 hr	10 ppm	MacPhee and Ruelle (1969)
Blasting agent (6 percent No. 2 diesel oil and 92 percent NH_4 and SO_4)				
- Ammonia	Salmonids	Acute	0.2-0.7	Willingham, et al. (1979)
	Freshwater aquatic life	Chronic	0.02	Willingham, et al. (1979)
- No. 2 diesel oil and gasoline	Pink salmon juveniles	Chronic	0.40[b/]	Moles and Rice (1983)
	Coho salmon juveniles	50 percent avoidance	1.80[b/]	Maynard and Weber (1981)
	Coho salmon adults	50 percent avoidance	3.2[b/]	Weber et al. (1981)
	Mysid (*Mysidopsis bahia*)	48-hr LC50	0.9	Anderson et al. (1974)
	Grass shrimp (*Palaeomonetes pugio*)	96-hr LC50	3.5	Anderson et al. (1974)
	Brown shrimp (*Penaeus aztecus*)	96-hr LC50	4.9	Anderson et al. (1974)
	Sheepshead minnow (*Cyprinodon variegatus*)	96-hr LC50	6.3	Anderson et al. (1974)
	Silverside (*Menidia beryllina*)	96 hr LC50	3.9	Anderson et al. (1974)
Lime	Freshwater aquatic life			
Methyl isobutyl carbinol (MIBC)	Fathead minnow	Acute	100-1000	Jennett and Callier (1977)
Propylene glycol methyl ether (Dowfroth 250)	Snail and crayfish	Acute	$\geq$100	Jennett and Callier (1977)
	Fathead minnow	Acute	1000	Jennett and Callier (1977)
	Bluegill	Acute	1000	Jennett and Callier (1977)
Chlorine	Juvenile salmonids	Acute	$\geq$0.057	Larson et al. (1978)
	Freshwater organisms	Chronic	0.003	Brungs (1976)
Phosphorus pentasulfide (in Nokes)				
- Hydrogen sulfide	Silver and king salmon	Acute and Chronic	0.3-1.2	Van Horn (1959) and Dimick (1952) cited in McKee and Wolf (1971, p. 200)
Sodium carboxymethyl cellulose (CMC)	No data available			

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TABLE 13-3 (Continued)

Substance	Species Tested	Type of Test Or Response Measured	Toxic Conc., mg/l	Reference
1-Hexanol (ALFOL)	No data available			
Sodium silicate	*Daphnia magna*	Acute	247	Hawley (1972)
	Rainbow trout (fingerlings)	Acute	256	Hawley (1972)
Sodium lauryl triethylene sulfate (Stephanfloat)[f/]	Fish	Lethal	6-7	Leclerc and Devlaminck (1952) as reported in McKee and Wolf (1971, p. 400)
Cationic homopolymer (M502)	Test data not available			

a/ Criterion pertains to water quality with a pH of 8.0 and water temperature of 5° C.

b/ In terms of total aromatic hydrocarbons.

c/ Effects on swimming performance and fat synthesis at a water temperature of 6° C.

d/ Aerodri 100 is a drying agent also called sulfosuccinic acid (Poling 1982, p. 70). According to The Merck Index (1968), sulfosuccinic acid is also called dioctyl sodium sulfosuccinate.

e/ Toxicity data pertains to the sulfa-dioctyl sodium salt of succinic acid.

f/ Data for sodium lauryl sulfate.

Assuming the spill frequency is a function of pipeline length, expected spills at the Quartz Hill project probably would be much less frequent than those in Washington. Using differences in pipeline lengths between Washington (240 mi) and the Quartz Hill project (1.5 mi) to form a ratio (240/1.5 = 160) for projecting probable spill frequencies on the Quartz Hill scenario, the risks of spills from pipeline failures appear to be small. A projected probable frequency for spills of 100 to 450 gal is once every 1,760 years. Spills of 420 to 4,200 gal might occur once every 1,504 years. And spills of 4,200 to 42,000 gal probably would occur once every 4,160 years. While this method of estimating spill probabilities suggests that frequencies of spills are quite low, projections of probabilities from one scenario to another may be questionable. These estimates, therefore, must be regarded only as approximations of risk, but they are derived from a scenario more appropriate to Quartz Hill than other data bases that exist.

The biological effects of a spill are discussed more fully in the section on impacts to marine biological resources. If the spill reached Tunnel Creek or Wilson Arm, effects on marine life inhabiting intertidal zones and marshes at the mouths of Tunnel Creek and the Wilson River could range from insignificant to significant, depending on the amount of oil reaching the estuary and existing environmental conditions. Diesel oil entering Tunnel Creek probably would cause significant losses of fish, including developing eggs, if spilled when salmon were spawning or eggs incubating. Effects would be moderate at other times of the year.

APPENDIX G

SECTION 14

PROBABILITY AND POTENTIAL EFFECTS OF OIL SPILLS IN MARINE WATERS

For project operation, large quantities of fuel oil (No. 2 type, diesel oil) and gasoline would be shipped to a marine terminal near the mouth of the Wilson River. Marine tankers (35,000 DWT) would be used to ship fuel oil, each with a payload of 6,750,000 gal, up Smeaton Bay and Wilson Arm. Since the annual consumption of oil would be 64,684,000 gal, 10 tanker deliveries would be required. Gasoline, including aviation fuel, would be shipped by barge in 27,500 gal lots, and 10 or 11 deliveries per year would supply an annual demand of 285,000 gal. Shipments and off-loadings of such large quantities of oil constitute a potentially serious hazard for biota in Smeaton Bay, Wilson Arm, and the Wilson River tidal flat. A worst case accident could release over a million gallons of oil during conditions that would drive it upfjord in Wilson Arm and eliminate entire runs of salmon and/or their food sources in the estuary. Spills of lesser magnitude could also have serious impacts on aquatic life, depending when and where they might occur.

The probability of an oil spill in Smeaton Bay and Wilson Arm depends upon many factors: vessel pilotage, traffic, navigational hazards, weather, sea conditions, and mechanical integrity. Accurate estimates of oil spill potential would require a thorough and site-specific investigation for these parameters. While such an investigation has not been made for Smeaton Bay and Wilson Arm, there is a basis for estimating an oil spill risk from studies of spill frequency potentials in Puget Sound. These studies were performed by the Oceanographic Institute of Washington (1978) and analyzed for the U.S. Coast Guard by Dames and Moore (1979). This joint effort produced estimates of oil spill probabilities for tankers in transit and at berth in Puget Sound in terms of frequencies and magnitudes. The results for either type of spill event provide a quantitative base for projecting probabilities from Puget Sound scenarios to in-transit and at-berth scenarios in Smeaton Bay and Wilson Arm. These projected probabilities, and descriptions of projection formulae, are shown in Appendix G, Tables 14-1 and 14-2. This method of spill-risk analysis involves several broad assumptions about similarities between Puget Sound and Smeaton Bay, and the reliability of these projected probabilities may be questionable. However, credible analyses of spill-risk probabilities for oil tanker accidents are limited to a few scenarios, and most of these are not as extensive as the Puget Sound analysis, nor are they as appropriate to the Misty Fiords environment.

Projected spill probabilities (Appendix G, Tables 14-1 and 14-2) indicate that spill frequencies are much greater when tankers are at berth off-loading oil than when they are in transit. Spills of 75 to 315 gal might be expected to occur at the marine terminal in Wilson Arm once every 116 years, while the same magnitude of spill from tankers in transit might occur once every 3,375 years. The probable at-berth

TABLE 14-1
ESTIMATED PROBABILITY OF OIL SPILL FREQUENCIES AND MAGNITUDES FROM TANKERS (35,000 DWT) IN TRANSIT ON SMEATON BAY AND THE WILSON ARM[a/]

SPILL MAGNITUDE (IN GAL.)	ESTIMATES FOR PUGET SOUND (1977) SPILL FREQUENCY & 95% CONF. INT. (YEARS/SPILL). ONE SPILL EVERY:	PROJECTED ESTIMATES FOR SMEATON/WILSON[b/] SPILL FREQUENCY & 95% CONF. INT. (YEARS/SPILL). ONE SPILL EVERY:
75.6 - 315	2.1 yr. (1.1 - 15.0)	3,375 yr. (1,768 - 24,107)[c/]
315 - 1,575	5.7 " (3.1 - 40.2)	9,160 " (4,982 - 64,602)
1,575 - 3,150	18.2 " (9.8 - 127.2)	29,247 " (15,748 - 204,408)
3,150 - 6,300	13.6 " (7.3 - 95.4)	21,855 " (11,731 - 153,306)
6,300 - 63,000	18.2 " (9.8 - 127.2)	29,247 " (15,748 - 204,408)
63,000 - 315,000	15.6 " (8.4 - 109.1)	25,069 " (13,499 - 175,322)
More than 315,000	36.3 " (19.6 - 254.5)	58,334 " (31,497 - 408,981)

a/ Based on data provided by the Oceanographic Institute of Washington (1978) for total number of calls to Puget Sound ports (all tanker sizes) in 1977, and summarized by Dames & Moore (1979).

b/ Conversion Factor = $\frac{1543 \text{ tankers/yr.}}{10 \text{ tankers/yr.}}^{1/} \; \frac{1}{0.8}^{2/} \; \frac{50 \text{ mi}}{6 \text{ mi}}^{3/} = 1607$

1/ Numerator: The number of oil tankers frequenting Puget Sound in 1977 (Dames & Moore 1979, p. 3-99). The average annual tanker frequency in Puget Sound covering 1975-77 (Dames & Moore 1979) and 1982-83 (U.S. Coast Guard Contact Report March 1984) is 1,424 tankers, with a standard deviation of 228 tankers.

Denominator: The number of oil tankers to frequent Smeaton Bay and Wilson Arm annually.

2/ Eighty percent of oil tankers in Puget Sound fall into the size range of 35,000 to 70,000 DWT (U.S. Coast Guard Contact Report, March 1984). This expression is inverted in the CF equation because spill-frequency probabilities are expressed as years/spill rather than spills/year.

3/ Numerator: The average one-way transit distance for tankers in Puget Sound, estimated by the U.S. Coast Guard (Contact Report, March 1984).

Denominator: The one-way transit distance for a tanker in Smeaton Bay and Wilson Arm.

c/ Projection of confidence intervals: o Lower confidence limit for Wilson Arm (LCL_{WA})

$$LCL_{WA} = \frac{(LCL_{PS})\,(SF_{WA})}{(SF_{PS})}$$

o LCL_{PS}: lower conf. limit for Puget Sound
o SF_{WA}: spill frequency for Wilson Arm
o SF_{PS}: " " for Puget Sound

o Upper confidence limit for Wilson Arm (UCL_{WA})

$$UCL_{WA} = \frac{(UCL_{PS})\,(SF_{WA})}{(SF_{PS})}$$

o UCL_{PS}: upper conf. limit for Puget Sound

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SECTION 14

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The probability of an oil spill in Smeaton Bay and Wilson Arm depends upon many factors: vessel pilotage, traffic, navigational hazards, weather, sea conditions, and mechanical integrity. Accurate estimates of oil spill potential would require a thorough and site-specific investigation for these parameters. While such an investigation has not been made for Smeaton Bay and Wilson Arm, there is a basis for estimating an oil spill risk from studies of spill frequency potentials in Puget Sound. These studies were performed by the Oceanographic Institute of Washington (1978) and analyzed for the U.S. Coast Guard by Dames and Moore (1979). This joint effort produced estimates of oil spill probabilities for tankers in transit and at berth in Puget Sound in terms of frequencies and magnitudes. The results for either type of spill event provide a quantitative base for projecting probabilities from Puget Sound scenarios to in-transit and at-berth scenarios in Smeaton Bay and Wilson Arm. These projected probabilities, and descriptions of projection formulae, are shown in Appendix G, Tables 14-1 and 14-2. This method of spill-risk analysis involves several broad assumptions about similarities between Puget Sound and Smeaton Bay, and the reliability of these projected probabilities may be questionable. However, credible analyses of spill-risk probabilities for oil tanker accidents are limited to a few scenarios, and most of these are not as extensive as the Puget Sound analysis, nor are they as appropriate to the Misty Fiords environment.

Projected spill probabilities (Appendix G, Tables 14-1 and 14-2) indicate that spill frequencies are much greater when tankers are at berth off-loading oil than when they are in transit. Spills of 75 to 315 gal might be expected to occur at the marine terminal in Wilson Arm once every 116 years, while the same magnitude of spill from tankers in transit might occur once every 3,375 years. The probable at-berth

APPENDIX G

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SPILL MAGNITUDE (IN GAL.)	ESTIMATES FOR PUGET SOUND (1977) SPILL FREQUENCY & 95% CONF. INT. (YEARS/SPILL). ONE SPILL EVERY:	PROJECTED ESTIMATES FOR SMEATON/WILSON[b/] SPILL FREQUENCY & 95% CONF. INT. (YEARS/SPILL). ONE SPILL EVERY:
75.6 - 315	2.1 yr. (1.1 - 15.0)	3,375 yr. (1,768 - 24,107)[c/]
315 - 1,575	5.7 " (3.1 - 40.2)	9,160 " (4,982 - 64,602)
1,575 - 3,150	18.2 " (9.8 - 127.2)	29,247 " (15,748 - 204,408)
3,150 - 6,300	13.6 " (7.3 - 95.4)	21,855 " (11,731 - 153,306)
6,300 - 63,000	18.2 " (9.8 - 127.2)	29,247 " (15,748 - 204,408)
63,000 - 315,000	15.6 " (8.4 - 109.1)	25,069 " (13,499 - 175,322)
More than 315,000	36.3 " (19.6 - 254.5)	58,334 " (31,497 - 408,981)

a/ Based on data provided by the Oceanographic Institute of Washington (1978) for total number of calls to Puget Sound ports (all tanker sizes) in 1977, and summarized by Dames & Moore (1979).

b/ Conversion Factor = $\frac{\text{1543 tankers/yr.}}{\text{10 tankers/yr.}}$ [1/] $\frac{1}{0.8}$ [2/] $\frac{\text{50 mi}}{\text{6 mi}}$ [3/] = 1607

1/ Numerator: The number of oil tankers frequenting Puget Sound in 1977 (Dames & Moore 1979, p. 3-99). The average annual tanker frequency in Puget Sound covering 1975-77 (Dames & Moore 1979) and 1982-83 (U.S. Coast Guard Contact Report March 1984) is 1,424 tankers, with a standard deviation of 228 tankers.

Denominator: The number of oil tankers to frequent Smeaton Bay and Wilson Arm annually.

2/ Eighty percent of oil tankers in Puget Sound fall into the size range of 35,000 to 70,000 DWT (U.S. Coast Guard Contact Report, March 1984). This expression is inverted in the CF equation because spill-frequency probabilities are expressed as years/spill rather than spills/year.

3/ Numerator: The average one-way transit distance for tankers in Puget Sound, estimated by the U.S. Coast Guard (Contact Report, March 1984).

Denominator: The one-way transit distance for a tanker in Smeaton Bay and Wilson Arm.

c/ Projection of confidence intervals: o Lower confidence limit for Wilson Arm (LCL_{WA})

$$LCL_{WA} = \frac{(LCL_{PS})\ (SF_{WA})}{(SF_{PS})}$$

o LCL_{PS}: lower conf. limit for Puget Sound
o SF_{WA}: spill frequency for Wilson Arm
o SF_{PS}: " " for Puget Sound

o Upper confidence limit for Wilson Arm (UCL_{WA})

$$UCL_{WA} = \frac{(UCL_{PS})\ (SF_{WA})}{(SF_{PS})}$$

o UCL_{PS}: upper conf. limit for Puget Sound

TABLE 14-2

ESTIMATED PROBABILITY OF OIL SPILL FREQUENCIES AND MAGNITUDES FROM TANKERS (35,000 DWT) AT BERTH IN THE WILSON ARM[a/]

SPILL MAGNITUDE (IN GAL.)	ESTIMATES FOR PUGET SOUND (1977) SPILL FREQUENCY & 95% CONF. INT. (YEARS/SPILL). ONE SPILL EVERY:	PROJECTED ESTIMATES FOR SMEATON/WILSON[b/] SPILL FREQUENCY & 95% CONF. INT. (YEARS/SPILL). ONE SPILL EVERY:
75.6 - 315	0.6 yr. (0.4 - 0.9)	116 yr. (70 - 174)[c/]
315 - 1,575	1.6 " (1.2 - 2.6)	309 " (232 - 502)
1,575 - 3,150	12.8 " (9.3 - 20)	2,470 " (1,795 - 3,859)
3,150 - 6,300	19.2 " (14 - 31)	3,706 " (2,702 - 5,984)
6,300 - 63,000	12.8 " (9.3 - 20)	2,470 " (1,795 - 3,859)
63,000 - 315,000	95.8 " (70 - 154)	18,489 " (13,510 - 29,721)
More than 315,000	191.6 " (139 - 308)	36,979 " (26,827 - 59,444)

a/ Based on data provided by the Oceanographic Institute of Washington (1978) for total number of calls to Puget Sound ports in 1977, and summarized by Dames & Moore (1979, p. 3-125).

b/ Conversion Factor = $\frac{1543 \text{ tankers/yr.}}{10 \text{ tankers/yr.}}^{1/} \; \frac{1}{0.8}^{2/} = 1607$

1/ Numerator: The number of oil tankers frequenting Puget Sound in 1977 (Dames & Moore 1979, p. 3-99). The average annual tanker frequency in Puget Sound covering 1975-77 (Dames & Moore 1979), and 1982-83 (U.S. Coast Guard Contact Report March 1984) is 1,424 tankers, witn a standard deviation of 228 tankers.

Denominator: The number of oil tankers expected to frequent Wilson Arm annually.

2/ 80 percent of oil tankers in Puget Sound fall into the size range of 35,000 to 70,000 DWT (U.S. Coast Guard Contact Report March 1984). This expression is inverted in the CF equation because spill-frequency probabilities are expressed as years/spill rather than spills/year.

c/ Projection of confidence limits: Same method as shown in Table 14-1.

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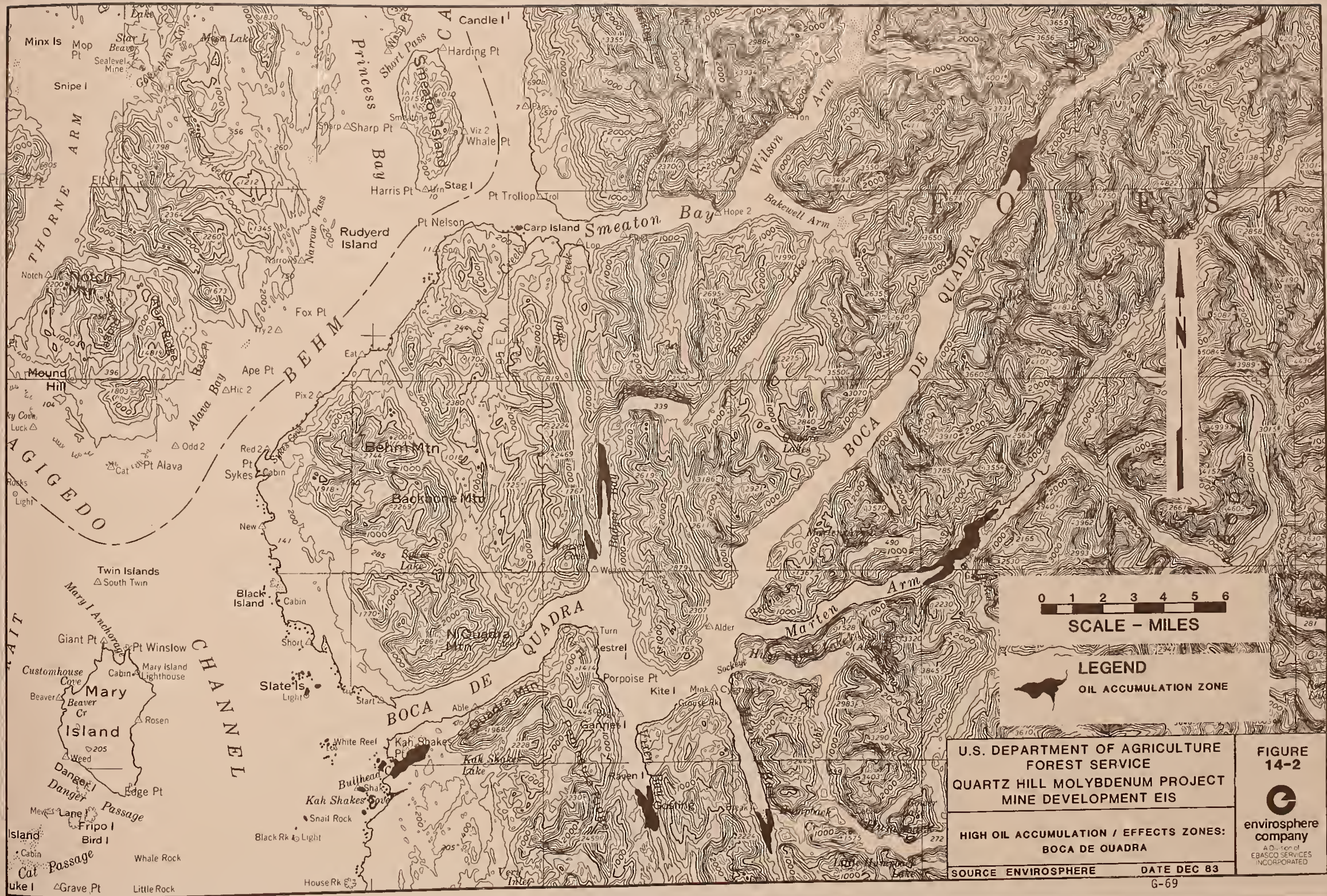
spill frequency is approximately twice the duration of the Quartz Hill mining project, but the probable in-transit spill frequency lies well beyond the scope of reasonable expectation. Off-loading spills of up to 1,575 gal might be expected once every 309 years in Wilson Arm--a frequency probability that is remote but considerable. But off-loading spills greater than 1,575 gal would probably occur only once in >2,000 years, and in-transit spills of similar magnitudes might occur once in >20,000 years. Either event is very unlikely. The most devastating event--spilling over 300,000 gal of oil under the worst containment conditions--would not likely occur more than once every 30,000 to 60,000 years.

When oil is spilled, part of it will evaporate, some will dissolve or emulsify, a portion will strand on the beach, and the remainder will settle to the bottom after weathering or sorbing to particulate material. Some of the oil will bind to particulate matter and eventually sink to the bottom, where it has only limited availability to marine life (Ho and Karim 1978; Roesijadi et al. 1978b). Over a number of years much of the oil will be converted into carbon dioxide and water by microorganisms (Watkinson 1978). The fates of spilled diesel oil and gasoline will be unique to each area and spill, and depend upon what environmental conditions--wind, waves, turbulence, temperature--exist during and subsequent to spillage. Diesel oil is a light oil that evaporates rather quickly, and is relatively soluble in relation to other petroleum products, including crude oil. Gasoline is even more soluble, but evaporates and is otherwise degraded and dispersed more quickly than diesel oil (Roubal et al. 1979). Because of evaporation, there is proportionately less of both products to clean up when spilled compared to other products. Like most petroleum products, diesel oil and gasoline can be expected to be blown and swept from higher energy areas (e.g., exposed rocky cliffs) to lower energy ones (e.g., the estuarine marsh habitats at the mouth of the Wilson River) (Research Planning Institute 1980). Sites of probable oil accumulation following spillage in Wilson Arm/Smeaton Bay and in Boca de Quadra are shown in Appendix G, Figures 14-1 and 14-2. These were identified as most probable accumulation sites because they are the only shallow and deeply recessed shelves and embayments in these fjords where wind-swept oil would gather. Oil accumulation sites in Wilson Arm/Smeaton Bay are more relevant to this assessment because they will be exposed to much greater quantities and frequencies of oil shipments.

Diesel oil and gasoline are quite toxic to marine life because of their relative water solubilities and elevated content of aromatic hydrocarbons like naphthalene. Effects of floating diesel oil or gasoline that strands on beaches (intertidal habitats) can be expected to be severe, especially to organisms like limpets and snails, which cannot seal themselves off from the oil (Cardwell 1973). In the subtidal region next to shore, the extent of mortalities will depend upon the degree to which the petroleum is driven into the water column by wave action. Due to the normally quiescent environment of Wilson Arm, severe mortality of intertidal organisms would not be expected unless the spill was very large (i.e., thousands of gallons spilled).


U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
HIGH OIL ACCUMULATION / EFFECT ZONES:
WILSON ARM - SMEATON BAY
SOURCE ENVIROSPHERE
DATE DEC 83
FIGURE
14-1
envirosphere
company
A Division of
EBASCO SERVICES
INCORPORATED
LEGEND
OIL ACCUMULATION ZONE
0
1/2
1
2
SCALE - MILES
N
CANAL
NATIONAL MONUMENT
SMEATON BAY
WILSON ARM
WILSON
BAKEWELL ARM
Candle Island
Harding Pt
Whale Pt
Pt Trollop
Pt Nelson
Carp Island
T 75 S
T 76 S



U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
FIGURE 14-2
envirosphere company
A Division of EBASCO SERVICES INCORPORATED
HIGH OIL ACCUMULATION / EFFECTS ZONES: BOCA DE QUADRA
SOURCE ENVIROSPHERE
DATE DEC 83
LEGEND
OIL ACCUMULATION ZONE
SCALE - MILES
0 1 2 3 4 5 6
N
FOREST
BOCA DE QUADRA
Marten Arm
Smeaton Bay
Wilson Arm
Bakewell Arm
BEHM CANAL
Princess Bay
Rudyerd Island
Smeaton Island
THORNE ARM
REVILLAGIGEDO CHANNEL
Mary Island
Twin Islands
Slate Is
Black Island
Kah Shakes Cove
Behm Mtn
Backbone Mtn
N Quadra Mtn
Alava Bay
Pt Alava
Pt Sykes
Pt Nelson
Pt Trollop
Carp Island
Harris Pt
Sharp Pt
Whale Pt
Harding Pt
Candle I
Minx Is
Snipe I
Mound Hill
Fox Pt
Ape Pt
Giant Pt
Pt Winslow
Mary Island Lighthouse
Customhouse Cove
Edge Pt
Danger Passage
Cat Passage
Fripo I
Bird I
Whale Rock
Little Rock
Grave Pt
White Reef
Snail Rock
Black Rk
House Rk
Porpoise Pt
Kite I
Gannet I
Raven I
Kestrel I
Alder
Sockeye
Humpback

Spills of diesel oil have caused major mortalities of marine life, mainly when prevailing storms drove oil into the water column, bottom, and marshes as reported by North et al. (1965) for the TAMPICO MARU in Baja, California, and by Sanders (1978) for the barge FLORIDA in Massachusetts. If the worst possible, but highly improbable, spill event happened and >100,000 gal of diesel oil reached the Wilson River tidal flat while smolts of pink, chum, coho, and chinook salmon were in residence, a major impact on their populations would occur. More than 1,000,000 juvenile salmon could be lost (see Table 3-10), as well as their food sources. Marshes are especially vulnerable to oiling and retention of oil because they are low energy habitats and possess large amounts of sediment for which oil has an affinity (Research Planning Institute 1980). Marsh habitats such as those at the mouth of Tunnel Creek and the Wilson River would be expected to incur a significant impact from oil spilled in the vicinity of the wharf.

Oil dissolved in the water column can be acutely toxic to marine life and, in fact, some of the aromatic constituents of diesel oil and gasoline, such as naphthalene and benzopyrene, can be very toxic (in parts per billion range) and even carcinogenic (e.g., Anderson et al. 1974; King 1977). In Wilson Arm only moderate mortalities of marine life--probably those inhabiting the uppermost few meters of water--would be expected because the fjord is a relatively low energy environment subject to limited influence by currents and waves. Certain species of phytoplankton, zooplankton, and ichthyoplankton would be most affected because organisms with large surface area to volume ratios are most susceptible.

The potential for chronic toxicity to aquatic life, whether lethal or sublethal, would be moderate in the vicinity of the spill. Effects could last up to a decade in habitats most susceptible to oiling, particularly the protected embayments and marshes (Appendix G, Figures 14-1 and 14-2; Sanders 1978). Good oil spill containment and cleanup, coupled with environmental conditions favoring evaporation and dispersion of the oil, could moderate impacts.

The hydrocarbons in diesel oil and gasoline are taken up and bioaccumulated by many species of marine fish and invertebrates, but most assimilated hydrocarbons are excreted (i.e., depurated) when the organisms are removed to clear sea water (Anderson 1979). Thus, the potential for magnification of these hydrocarbons when predator eats prey is considered insignificant. There is a problematic impact associated with consuming fish from oil-contaminated areas, for fish may take up enough hydrocarbons to taint their flesh (Howgate et al. 1977, p. 145). The potential impact on people is considered insignificant because the area affected by the oil spill would likely be closed temporarily to harvest and because most hydrocarbons would be depurated relatively rapidly when the fish enter uncontaminated waters. Residual concentrations of polynuclear aromatic hydrocarbons (Varanasi and Gmur 1981), some of which are known to be carcinogenic, pose a problematic impact that is judged insignificant at this juncture because actual harm to people from these compounds from previous oil spills remains undocumented.

The adverse effects of oil spills on birds are well documented. Oil eliminates much of the insulative and buoyant capacity of feathers, and causes high mortalities via hypothermia and drowning. Despite these major impacts, Eastin and Hoffman (1979) assert that oil spills pose the greatest threat to the reproductive and development periods of the life cycles of aquatic birds.

APPENDIX G

SECTION 15

POTENTIAL EFFECTS OF CHEMICAL SPILLS IN MARINE WATERS

A number of chemicals other than petroleum are used in sufficiently large amounts in the mining and milling process to warrant concern about environmental effects should they be spilled during transit or unloading at the Wilson Arm wharf. The probability of a chemical spill appears very low because no spills of ecological significance have been reported to the National Oceanic and Atmospheric Administration's Alaskan Hazardous Materials Response Project in 1981 and 1982, and there were 2,566 shipments of hazardous materials into the state in 1982 (Kennedy 1983). At Quartz Hill, where 17 shipments per year are contemplated (Cronin 1983a), the probability of spillage appears even more remote.

The chemicals that will be shipped in large amounts to the project and the amounts estimated for each shipment are given in Appendix G, Table 15-1.

Limited information is available on the environmental toxicology and chemistry of most of the compounds. Available information on aquatic toxicity is summarized in Appendix G, Table 13-3. These data have been used to estimate the volume of the fjord affected should a large chemical spill occur. These volumes are presented in Appendix G, Table 15-1.

Information on the solubility, chemical reaction products, toxicology, bioaccumulation potential, and degradation rates of these products is needed for a more complete assessment of the environmental hazard should they be spilled. Read and Manser (1976) and Hawley (1972) provide limited information for several of the reagents. For example, methyl isobutyl carbinol and polyglycol ether (Dowfroth 250) adsorb strongly to particular types of surfaces like tailings. The carbinol is readily biodegraded, but the polyglycol ether is not.

The chemicals discussed below may be toxic to marine life if spilled. The assumption is made that the chemicals dissolve immediately upon spillage and that the entire cargo in every 3-week shipment will enter the water.

Calcium oxide's (lime) aquatic toxicity is a pH effect, because the reaction, $Ca + H_2O \Longrightarrow Ca(OH)_2$, creates alkaline conditions. A pH of 8.5 is the upper limit for marine waters according to Alaska's water quality standards. A spill of 30,000 lbs of lime may increase the pH above 8.5 in a volume less than $5,366 \times 10^6$ ft^3 (Appendix G, Table 15-2). There are no long-term human health or ecological consequences associated with a spill of this chemical because it is readily degraded.

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TABLE 15-1
AMOUNTS OF MILLING REAGENT CHEMICALS
ESTIMATED TO BE TRANSPORTED TO MINE

Chemical	Annual Usage (lbs)	Containers/ Year 1/	Containers/ Shipment 2/	Amount Spilled (lbs) 3/	Volume at Potentially Toxic Concentration x 10^6 ft^3
Blasting Agent 4/	16,790,000	420	25	1,000,000	4,174
Dowfroth	87,600	...	1	43,800	1.35
ALFOL	1,314,000	35	3	113,190	
Nokes 5/	1,576,800	1,107			
NaOH			32	4,560	no toxicity data
P_2S_5			32	4,560	35,592-26,334
MIBC	2,569,600	70	5	185,075	0.092
Stepanfloat	321,200	7	1	45,886	74,969
Sodium Silicate	1,839,600	40	1	45,990	9.68
CMC	1,314,000	88	6	90,000	no toxicity data
M502	5,810,800	124	1	46,860	no toxicity data
SF330	293,000	2,086	120	16,800	18,043
Lime	3,912,800	261	3	44,975	<3,580
Aerodri	5,840	12	4 6/	1,481	2,366
Chlorine	10,200	68	4	600	168,499

1/ From Appendix G, Table 13-1.
2/ Based on delivery at 3 week intervals (all numbers have been rounded up to account for the worst case) or maximum of 1 container per trip when usage is low and regular delivery will not be required.
3/ Containers times lbs/container.
4/ Ammonium nitrate will be shipped in 20 ton (40,000 lb) containers (Sheflott 1984).
5/ The Nokes reagent is a mixture of NaOH and P_2S_5. These reagents are mixed in approximately equal proportions, therefore it is assumed that equal amounts of each will be contained in each shipment. Formation of H_2S is the primary concern with respect to toxicity (see Table 15-3).
6/ Delivered every 3 months.

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TABLE 15-2

METHOD FOR CALCULATING TOXICITY IN SALTWATER FROM A SPILL OF CALCIUM OXIDE

---

1. Ksp $Ca(OH)_2 == Ca^{++} 2(OH^-)$

Assume $\frac{[Ca][OH]^2}{[Ca(OH)^2]} = 5.5 \times 10^{-6}$

$[Ca][OH]^2 = 5.5 \times 10^{-6}$

$[.5\ OH][OH]^2 = 5.5 \times 10^{-6}$

$(OH)^3 = \frac{5.5 \times 10^{-6}}{.5}$

$==> [OH] = 2.22 \times 10^{-2}$

$pOH = 1.65 ==> pH == 12.35$ Maximum theoretical pH at saturation, equilibrium

2. Concentrations vs pH:

pH = 8.5 ==>	pOH 5.5 ==>	$[OH] = 3.2 \times 10^{-6}$ moles OH/l
9.0	5.0	$= 1.0 \times 10^{-5}$
9.5	4.5	$= 3.16 \times 10^{-5}$
10.0	4.0	$= 1.0 \times 10^{-4}$
10.5	3.5	$= 3.162 \times 10^{-4}$
11.0	3.0	$= 1.0 \times 10^{-3}$

2 moles OH per mole $Ca(OH)_2$ (or mole CaO) (pure water)
for PH

8.5 ==>	1.6×10^{-6} moles CaO/l
9.0	5.0×10^{-6}
9.5	1.58×10^{-5}
10.0	5.0×10^{-5}
10.5	1.58×10^{-4}
11.0	5.0×10^{-4}

A spill of phosphorous pentasulfide could be toxic to aquatic life because hydrolysis yields a moderately strong acid and hydrogen sulfide (H_2S): $P_2S_5 + 8H_2O ==> 2H_3PO_4 + 5H_2S$. Accordingly, toxicity is a function of the hydrogen sulfide concentration, pH, water temperature, and dissolved oxygen. Smith et al. (1979) recommend a maximum concentration of 0.002 mg/l as H_2S. The volume of seawater affected by a spill of P_2S_5 cannot be predicted readily because the effect of phosphoric acid (H_3PO_4) affects the buffering capacity of seawater, which affects the H_2S concentrations. Potential impacts are best determined via laboratory experimentation. However, the impact would not be trivial, as revealed by the calculations in Appendix G, Table 15-3. At pH 8, where only 13.5 percent of the hydrogen sulfide would consist of the toxic form, 35,592 x 10^6 ft^3 of water could possess a concentration of 0.002 mg/l. At pH 6, when 94 percent of the hydrogen sulfide would consist of the toxic form, 247,523 x 10^6 ft^3 could possess the 0.002 mg/l concentration. These estimates assume 0.002 mg/l of H_2S would be toxic to marine life in the project area, but better data are needed for verification. There is no long-term ecological or human health hazard associated with P_2S_5, which decomposes rapidly to natural substances.

Only very rough estimates can be made concerning worst case impact upon loss of entire cargos of Dowfroth 250 and methyl isobutyl carbinol. Both are believed to be acutely toxic to some aquatic species at concentrations between 100 and 1,000 mg/l (Appendix G, Table 15-4). At arbitrarily assumed average toxicities of 550 mg/l, the volumes of water that may be acutely toxic to aquatic organisms could range up to 92,000 ft^3 for MIBC and 1,350,000 ft^3 for Dowfroth. Methyl isobutyl carbinol's toxicity is limited by its relatively modest (1.7 percent by weight) water solubility (Hawley 1972). Methyl isobutyl carbinol is less dense than water (density = 0.81) and may be of greater concern for its effect on waterfowl, because it would exist partially as a slick. Its toxicity is expected to be short-lived, as it can be biodegraded by microorganisms (Read and Manser 1976).

Ammonium nitrate is used as an explosive. It dissociates ($NH_4NO_3 ==> NH_4^+ + NO_3^-$) into two compounds that are nutrients to plants and microorganisms, but which can also be toxic if present in sufficient concentration. The unionized form of ammonia (NH_3) is the toxic compound of greatest concern; it is formed, $NH_4^+ ==> NH_3 + H^+$, as a function of pH. At a pH of 8.3, only 2.45 percent of the total NH_4-N will be unionized, although it is known that ammonia is more toxic at higher salinities given constant pH (Willingham et al. 1979; European Inland Fisheries Advisory Commission 1973). Concentrations of 0.021[1/] and 0.084 mg/l[1/] NH_3 have been proposed as the uppermost safe concentration for acute[2/] and chronic[3/] exposure of aquatic life. A spill of 1,000,000 lbs of

1/ At a pH of 8.0 and water temperature of 5°C.
2/ Acute exposure may extend for up to 96 hours.
3/ Chronic exposure may extend for up to 30 days or more.

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TABLE 15-3
METHOD FOR CALCULATING THE TOXICITY OF
PHOSPHORUS PENTASULFIDE IN SALTWATER

A. Reaction of P_2S_5 in water

$222.27 + 8(18.02) \Longrightarrow 2(98.00) + 5(34.08)$
$P_2S_5 + 8H_2O \Longrightarrow 2H_3PO_4 + 5H_2S$

1. For each mole of P_2S_5 spilled, 5 moles of H_2S is formed, 45,600 lbs (20,684 kg) of P_2S_5 yields 34,958 lbs (15,857 kg) H_2S or 32,886 lbs (14,917 kg) as S.

2. Fraction of H_2S that would occur in the toxic form of molecular H_2S (from Broderius et al. 1977, p. 2325).

   a. $pKH_2S = 3.122 + 1132/273 + T(^\circ C)$
      $pKH_2S = 7.1939$

   b. $[H_2S]$
      $[\text{dissolved } S^-] = 1/(1 + 10^{pH-pk})$
      (1) at pH 8, $\frac{[H_2S]}{[S]} = 0.1352$

      at pH = 7 = 0.698
      at pH = 6 = 0.9399
      at pH = 5 = 0.9999

3. Therefore, the 29,834 kg of S spilled would consist of the following amounts of H_2S at the following pH values.

   a. At pH = 8 = (0.1352)(14,917 kg) = 2,017 kg.

      (1) $\frac{2{,}017 \text{ kg}}{\text{affected volume}} = 2 \times 10^{-9}$ kg/ (toxic concentration)

      (2) affected volume = $1{,}008 \times 10^6$ m^3

   b. At pH = 7 = (0.6098)(14,917) = 9,096 kg

      affected volume = $4{,}548 \times 10^6$ m^3

   c. At pH = 6 = (0.9399)(14,917 kg) = 14,020 kg

      affected volume = $7{,}010 \times 10^6$ m^3

   d. At pH = 5 = (0.9999)(14,917 kg) = 14,916 kg

      affected volume = $7{,}458 \times 10^6$ m^3.

TABLE 15-4

ESTIMATED VOLUME OF TOXIC SALTWATER
ASSOCIATED WITH SPILLS OF TOXIC CHEMICALS

I. Approximately 250 mg/l sodium silicate was found to be toxic to the freshwater crustacean *Daphnia* (Hawley 1972).

   1) 45,990 lbs (20,696 kg) could be spilled

   2) $\frac{20{,}696 \text{ kg}}{\text{affected volume}} = 250$ mg/l

      affected volume = 0.083×10^6 m^3

II. Based on very limited acute toxicity data for freshwater aquatic life only. Assume toxicity ranges between 100 and 1,000 mg/l, averaging 550 mg/l.

   A. Methyl Isobutyl Carbinol

      1. Up to 185,075 lbs (83,950 kg) could be spilled.

      2. Because only 1.7 percent by weight is soluble (Hawley 1972), only 3,146 lbs (1,427 kg) would be soluble

         a. $\frac{1{,}427 \text{ kg}}{\text{affected volume}} = 550$ mg/l

            affected volume = 0.0026×10^6 m^3

   B. Dowfroth 250

      1. 43,800 lbs (19,710 kg) may be spilled.

      2. $\frac{19{,}710 \text{ kg}}{\text{affected volume}} = 550$ mg/l

         affected volume = 0.0358×10^6 m^3

III. Chlorine: toxic concentration 0.057 mg/l. 600 lbs (272 kg) could be spilled.

   $\frac{272 \text{ kg}}{\text{affected volume}} = 0.057$ mg/l

   affected volume = $4{,}772 \times 10^6$

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TABLE 15-4 (Continued)

IV. Stepanflote: toxic concentration 6 mg/l. 45,886 lbs (20,649 kg) could be spilled.

$$\frac{20{,}649\ \text{kg}}{\text{affected volume}} = 6$$

affected volume = $3{,}441 \times 10^6\ m^3$

V. Aerodri: toxic concentration 10 mg/l. 1,481 lbs (672 kg) could be spilled.

$$\frac{672\ \text{kg}}{\text{affected volume}} = 10\ \text{mg/l}$$

affected volume = 67×10^6

VI. SF330: toxic concentration 570 mg/l. 16,800 lbs (291,200 kg) could be spilled.

$$\frac{291{,}200\ \text{kg}}{\text{affected volume}} = 570\ \text{mg/l}$$

affected volume = $511 \times 10^6\ m^3$

NH_4NO_3 (Appendix G, Table 15-5) could have a significant acute effect on marine life. A volume of 4,174 x 10^6 ft^3 theoretically could possess an unionized ammonia concentration of 0.020 mg/l. The long-term impact of an ammonium nitrate spill probably would be transiently beneficial by stimulating blooms of aquatic plants. There is no long-term ecological or human health hazards associated with a spill of ammonium nitrate, as the compounds are degradable.

There was insufficient information available concerning the toxicology of M502, CMC, and ALFOL to permit an evaluation of the potential consequences of a spill of these chemicals.

Chlorine is used as a disinfectant in sanitary wastes. It is quite toxic in aquatic systems. Larson et al. (1978) found acute effects from chlorine to juvenile salmonids at concentrations >0.057 mg/l. And it is known to be chronically toxic to freshwater organisms at 0.003 mg/l (Brungs 1976). If spilled into marine waters during transport, given the scenario shown in Appendix G, Table 15-1, toxic concentrations of chlorine could occur in a volume of 168,500 ft^3. While it would dissipate rapidly, losses of fish, invertebrates, and phytoplankton could be expected. But due to the short duration of toxic chlorine concentrations, these losses would not be significant. An important exception to this, however, would involve a chlorine spill during the passage of a salmonid run. If they did not avoid the toxic water volume, salmonid losses could be significant.

SF330 is a polyacrylamide used in the milling process for frothing and resettling. Not much is known about its toxicity to marine life, but Hawley (1972) reported it to be acutely toxic to fathead minnows at about 570 mg/l. Spills of SF330 from transportation accidents into marine waters could cause a small volume of 18,000 ft^3 to become potentially toxic. Resulting losses of marine organisms in this volume would be too small to be significant.

Aerodri is a dewatering aide used to reduce moisture content and improve handling of mineral coke filters. It was found to be moderately toxic to chinook and coho salmon by MacPhee and Ruelle (1969), reporting mortalities at 3-7 hours in 10 mg/l. Only a small quantity (5,840 lbs) will be used annually. If spilled into Wilson Arm, the expected toxic volume would be 2,366 ft^3. This toxicity is too localized to be regarded as a significant hazard in a transportation accident scenario.

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TABLE 15-5

METHOD FOR CALCULATING TOXICITY IN SALTWATER FROM A SPILL OF AMMONIUM NITRATE

In Seawater

1. Assume loss of 1,000,000 lbs (453,600 kg).

2. Assume pH of 8.3 and that percent unionized NH_3 = 100/1 + antilog (pka - pH), where pka = 9.90 at water temperature of 5.0 (European Inland Fisheries Advisory Commission 1973). Should equal 2.45 percent unionized ammonia.

3. $\frac{NH_4}{NH_4NO_3} = \frac{17.03}{80.05} = 0.2127$

4. (453,600 kg NH_4NO_3)(0.2127) = 96,481 kg of NH_4

5. (0.0245 percent NH_3)(96,481 kg) = 2,364 kg at pH = 8.3 and T = 5°C

6. If upper limit of safe NH_3 concentration is 0.020 mg/l, then

$$= (2{,}364)(1{,}000)(1{,}000)\left(\frac{1 \text{ liter}}{0.020}\right)$$

$$= 1.182 \times 10^{11} \text{ l} = 1.182 \times 10^{8} \text{ m}^3$$

APPENDIX G

SECTION 16

METHODS AND CALCULATIONS OF TAILINGS SPILLS FROM ACCIDENTAL PIPELINE BREAKS AND ASSESSMENT OF POTENTIAL BIOLOGICAL EFFECTS

A. METHODS

1. To calculate the amount of tailings that could spill from a break in a tailings pipe, the following procedure was used:

1.1 Pipeline capacities:

- for 1 lineal ft. of a 24" pipe (assume 1/2 full):
  Volume of tailings = 0.058 cu. yds.
- for 1 lineal ft. of a 32" pipe (assume 1/2 full):
  Volume of tailings = 0.103 cu. yds.
- for 1 lineal ft. of launder 4 ft. x 3 ft. (assume 1/2 full):
  Volume of tailings = 0.222 cu. yds.
- for cylindrical drop box 10 ft. wide x 25 ft. deep:
  Volume of tailings = 72.72 cu. yds.

1.2 Discharge of tailings from mill:

- known:
  - intake capacity = 80,000 TPD
  - 0.13 percent of capacity is recovered as Mo
  - output of tailings is 23,646 GPM or 117.1 cu. yd./min.
  - specific gravity of tailings is 1.39
- assumptions:
  - 99.87 percent, or 79,896 TPD, are wasted as tailings
  - 70 percent of tailings are suspendable solids
  - 30 percent of tailings are settleable solids
    (based on tailings particle size distributions, Table II-8, U.S. Borax 1984a)

1.3 Solids in mill tailings:

- output of total solids is 50,333,522 g/min., or 427,861 g/cu. yd.
- output of suspendable solids is 35,233,465 g/min., or 298,677 g/cu. yd.
- output of settleable solids is 15,100,057 g/min., or 129,184 g/cu. yd.

1.4 Calculations for Table 16-1:

- o distance from mill to break:

  $$\text{dist. (km)} = \frac{(L1 + L2 + L3)}{3281}$$

  where L1 = length (ft.) of single 24" pipe
  L2 = " " " " 32" "
  L3 = " " " launder(s)
  3281 = ft. per km

- o amount spilled:

  - assume spill time is 60 min. unless pipe break is <2 km from mill, then spill time is assumed to be 30 min.

  - spill volume (cu. yd.) = V1 + V2 + V3 + V4 + V5
    where V1 = upstream contents of 24" pipe
    V2 = " " " 32" "
    V3 = " " " launder
    V4 = " " " drop boxes
    V5 = discharge from mill during spill time

- o suspended solids (S_{sus}) concentrations in streams:

  S_{sus} (g/l) = PQ/SQ
  where PQ = tailings flow from pipe in g/sec
  SQ = stream flow in l/sec using the following river data

Stream	Mean February Flow (l/sec)	Mean Stream Width (m)
Tunnel Creek	1,303	7
Blossom River	9,492	30
Keta River	10,185	35

- o settled solids depths in streams:

  - assumptions:
    - all settleable solids will settle in river in 60 min.
    - average stream depth is 5 percent of average stream width

  - volume of water per lineal meter of stream:
    $V\ (l/m) = (0.05\ \overline{w}^2)(1M)(1000\ l/m)$
    where $\overline{w}$ = mean stream width (see table used in this section, 1.4)

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TABLE 16-1

ESTIMATES OF AMOUNTS OF TAILINGS THAT COULD BE SPILLED INTO STREAMS AND FJORDS SHOULD A TAILINGS PIPELINE BREAK

Scenario No. and Mill Site	Disposal Alternative	Location of Break and Spill 1/	Receiving Waters	Distance: Mill to Break (km) 2/	Amount Spilled (cu yds)	Suspended Solids Conc. (g/l) 3/	Settled Solids: Area Covered (hectares)	Settled Solids: Depth Covered (cm)
1. Tunnel Creek	to inner basin of Boca de Quadra	surface of Boca	inner basin, Boca de Quadra	8.9	14,162	16.92 4/	1.0	12.3
2. Tunnel Creek	to central basin via shoreline extension from inner basin	surface of Boca	at sill separating inner from central basins	9.9	14,815	5.90 5/	1.0	12.8
3. Tunnel Creek	to central basin with extended launder	surface of Boca	central basin, Boca de Quadra	13.7	17,675	7.04 5/	1.0	15.3
4. Tunnel Creek	to central basin with scenario 1 launder and 24" pipe at shoreline	surface of Boca	central basin, Boca de Quadra	15.3	16,575	6.60 5/	1.0	14.3
5. Tunnel Creek	to central basin via direct tunnel alignment	surface of Boca	central basin, Boca de Quadra	12.2	16,518	6.58 5/	1.0	14.3
6. Tunnel Creek	to inner basin of Boca	upper Tunnel Creek	Tunnel Creek	0.2 6/	3,636	115.75	0.67	5.4
7. Tunnel Creek	to Wilson Arm	middle of Tunnel Creek	Tunnel Creek	1.0 6/	4,486	142.81	0.67	6.7
8. Tunnel Creek	to Wilson Arm	surface of Wilson	upper Wilson Arm	4.4	11,241	13.43 4/	1.0	9.7
9. Tunnel Creek	to Wilson Arm	surface of Wilson Arm near Bakewell Arm	Wilson/Bakewell Arms	14.7	15,789	6.29 5/	1.0	13.7
10. Beaver Creek	to Boca de Quadra	Raspberry Creek	Blossom River	1.5 6/	4,542	19.85	1.1	4.0
11. Beaver Creek	to Boca de Quadra	second launder exhance near Tunnel Creek	Tunnel Creek	6.0	11,265	717.28	1.3	16.8
12. Beaver Creek	inner basin of Boca de Quadra	at Keta River level	Keta River	10.5	15,839 7/	0.0	0.0	0.0
13. Beaver Creek	inner basin of Boca de Quadra	near surface of Boca	inner basin, Boca de Quadra	16.0	18,679	22.32 4/	1.0	16.2
14. Beaver Creek	inner basin w/alternative tunnel alignment	at surface of Boca	inner basin, Boca	14.4	18,672	22.31 4/	1.0	16.2
15. Beaver Creek	central basin of Boca de Quadra using extended 24" pipe	at surface of Boca	central basin, Boca	21.2	18,813	7.50 5/	1.0	16.3
16. Beaver Creek	to central basin of Boca using extended 24" pipe	at surface of Boca	inner basin, Boca	18.2	17,653	21.09 4/	1.0	15.3
17. Beaver Creek	to Wilson Arm	just below surface of Wilson	upper Wilson Arm	17.4	15,672	18.72 4/	1.0	13.6
18. Beaver Creek	to Wilson Arm	surface of Wilson Arm near Bakewell Arms	Wilson/Bakewell Arms	21.7	17,959	7.15 5/	1.0	15.5

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TABLE 16-1 (Continued)

Scenario No. and Mill Site	Disposal Alternative	Location of Break and Spill 1/	Receiving Waters	Distance: Mill to Break (km) 2/	Amount Spilled (cu yds)	Suspended Solids Conc. (g/l) 3/	Settled Solids: Area Covered (hectares)	Settled Solids: Depth Covered (cm)
19. Beaver Creek	to Wilson Arm	at Raspberry Creek	Blossom River	2.8	8,387	73.31	2.3	7.4
20. Beaver Creek	to Wilson Arm	at head of Wilson estuary	Wilson estuary and upper Wilson Arm	6.2	11,436	63.31 8/	1.0	9.9
21. North Meadow	to inner basin of Boca de Quadra	at Keta River	Keta River	7.1	10,762	67.66	2.1	10.3
22. North Meadow	to inner basin of Boca de Quadra	at Keta River estuary	Keta River estuary and inner Boca basin	13.7	13,255	79.18 8/	1.0	11.5
23. North Meadow	to inner basin of Boca de Quadra	at surface of Boca	inner basin of Boca	17.9	14,847	77.74 4/	1.0	12.9
24. North Meadow	to central basin of Boca de Quadra	at surface of Boca	central basin of Boca	25.2	17,634	7.02 5/	1.0	15.3
25. North Meadow	on-land disposal to Tunnel Creek tailings pond	at Raspberry Creek	Blossom River	7.1	9,962	67.07	2.3	8.7
26. North Meadow	on-land disposal to Tunnel Creek tailings pond	at Tunnel Creek	Wilson estuary and upper Wilson Arm	12.0	11,799	70.48 8/	1.0	10.2
27. North Meadow	on-land disposal to Arnitz Creek tailings pond	at Keta River	Keta River	6.6	10,123	62.46	2.1	9.7
28. North Meadow	on-land disposal to Arnitz Creek tailings pond	at Keta estuary	Keta River estuary and inner Boca basin	12.5	12,807	75.51 8/	1.0	11.1
29. Beaver Creek	on-land disposal to Tunnel Creek tailings pond	at Raspberry Creek	Blossom River	1.4	8,283	72.40	2.3	7.3
30. Beaver Creek	on-land disposal to Arnitz Creek tailings pond	at Keta estuary	Keta estuary and inner Boca basin	13.1	19,982	119.37 8/	1.0	17.3

1/ All broken pipe scenarios assume the loss of 2 pipes' contents: an avalanche or earthquake would break both parallel pipes in a worst case estimate; a break due to wear would probably involve only one pipe, but cause a greater flow of tailings (or 2 pipes' capacity) due to reduced in-pipe resistance.
2/ Assumed response time is 60 min., unless stated otherwise.
3/ For period of 12 hour.
4/ Assumed mean water depth of 25 m.
5/ Assumed mean water depth of 75 m.
6/ Assumed response time of 30 min., because of close proximity to mill.
7/ Entire spill is contained by an on-land catch basin with volume of 23,148 cu yds.
8/ Assumed mean water depth of 5 m.

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- area covered by settled tailings:

  $v\ (\mathrm{M/sec}) = \dfrac{\overline{Q}}{V}$

  where $\overline{Q}$ = mean stream flow (see table used in this section, 1.4)

  d (M traveled in 60 min.) = 3600v

  A (area covered by tailings in cm^2) = 10,000 $d\overline{w}$

- quantity of settleable solids (S_{set}) discharged into streams:

  $S_{set} = PS_{set} = MS_{set}$

  where PS_{set} = S_{set} from pipeline
  MS_{set} = S_{set} from mill (in 60 min.)

- depth of settled tailings in streams (Z_{set}):

  o assume 1.5 g of settled tailings will cover 1 cm^2 to a depth of 1 cm; therefore, the ratios of weight to area covered is 0.67, or 1 g S_{set} covers 1 cm^2 to a depth of 0.67 cm

  $Z_{set}(cm) = 0.67\ S_{set}/A$

o suspended solids (S_{sus}) in estuaries and fjords:

- assumptions:

  - all suspended solids concentrate over 1 hectare
  - mean depth ($\overline{z}$) for estuaries and upper fjords is 5 m
  - $\overline{z}$ for inner basin of Boca de Quadra is 25 m
  - $\overline{z}$ for central basin of Boca de Quadra and Wilson Arm is 75 m

  $$S_{sus}(g/l) = \frac{TS_{sus}}{1000\ Az}$$

  where TS_{sus} = total suspended solids spilled (in g)

o settled solids (S_{set}) = in estuaries and fjords:

- assumption:

  - all settled solids accumulate over an area of 1 hectare
  - depth of settled solids (Z_{set}):

    $Z_{set}(cm) = 0.67\ S_{set}/A$

B. RISKS OF BREAKS IN MILL TAILINGS PIPELINES

Mill tailings pipelines wear rapidly from the abrasive sediment and corrosive chemicals they carry. Rates of wear in these pipes are functions of the following: (1) pipe material and lineal curvatures, (2) milling reagents used, (3) particle size, composition, and texture of tailings, and 4) velocity

of tailings as determined by mill output and slope of pipe (Pelletier 1984). Past experience with wear in mill tailings pipelines indicates an expected lifetime of about 10 years. Careful monitoring of wear in these pipelines will add considerable assurance that weaknesses will be detected before ruptures occur. Extensive monitoring of pipeline wear will be conducted at the onset of mining using ultrasonic and support equipment, from which wear characteristics will be used to establish a schedule for routine monitoring. Worn pipe sections will be rotated or replaced based on detection of significant weakness. Pressure sensing instruments will be used to monitor internal changes within the pipelines. Detection of leakage in any section of the pipeline will alert mill operators to close appropriate valves to stop the flow of mill tailings. Passive monitoring by mine personnel will also occur continuously as they travel the access road running along Tunnel Creek (addressing here the proposed project). Pipeline ruptures would be immediately obvious to anyone traveling this road.

While rupture detection and prevention measures should be adequate to avoid tailings spills, additional steps will be taken to prevent an unlikely spill from reaching a sensitive aquatic environment. Precautionary spill trenches and catch basins will be installed along Tunnel Creek at the time of access road excavation that will have sufficient capacity to capture and hold all of the spilled tailings represented in scenario 7 of Table 16-1 (4,486 cu yd). This implies that even in the event of a pipeline failure near Tunnel Creek, fish populations would be protected by the engineered barriers. These barriers also include encasement pipes for sections passing over or near salmonid habitats. Pipelines crossing Tunnel Creek and running along Wilson Arm will be encased in larger pipes, which will serve to catch spilled tailings from those sections that have no parallel trenches. The encasement pipe crossing Tunnel Creek will empty into a parallel trench leading to the catch basin. Spills occurring along Wilson Arm would enter the encasement pipe and finally the dropbox leading to deep disposal in the fjord (see Appendix A, Section E for more details).

The foregoing risk analysis indicates that a pipeline failure is highly unlikely. Salmon populations are additionally secure because of engineered containment systems that are capable of preventing spilled tailings from entering aquatic environments. As such, the risk of impacts from spilled mill tailings on aquatic populations approaches zero.

C. BIOLOGICAL EFFECTS ASSESSMENT

Spills of mill tailings from pipeline breaks could deposit these wastes into streams, estuaries, or surface waters of fjords (Table 16-1). One of the spill scenarios considered has an on-land catch basin that prevents any of the tailings from entering aquatic environments (No. 9). A few of the spill scenarios involve on-land disposal ponds (Nos. 20, 21, 22, 23, 24, and 25), while the rest deliver tailings deep into either Wilson Arm or Boca de Quadra. Since all marine disposal alternatives will deposit tailings on the floors of these fjords, the amounts of tailings spilled and accumulated as settled solids may not be distinguishable from the intended deposition. These scenarios (Nos. 1, 2, 3, 6, 10, 11, 12, 13, 18, and 19) will reflect only potential impacts from suspended solids. Here, the expected suspended solids could concentrate in a range from 6 to 23 g/l. Streams and estuaries would be

impacted more severly from tailings spills (Nos. 4, 5, 7, 8, 9, 14, 15, 16, 17, 20, 21, 22, 23, 24, and 25). Settled solids could accrue to depths of 4 to 17 cm in benthic habitats. And suspended solids in these shallow environments could rise to hundreds of g/l for periods of <12 hours.

In general, a spill of tailings in Boca de Quadra or Wilson Arm would cause localized mortality mainly to intertidal and subtidal nonmobile benthos (e.g. clams, worms). Depending on the location, the spill would affect either the nearshore, estuary, or deep benthic habitats. The sedimentation depths will range from 9.9-17.3 cm (Appendix G, Table 16-1) in estuaries (Wilson or Keta) and may cause direct, but probably not complete, mortalities over the 1.0 hectare area of the estuary to the benthic organisms. If a tailings spill occurred in the Keta estuary, it would impact about 1.3 percent of the estuary (1 of 80 hectares). In the Wilson estuary about 0.7 percent (1 of 140 hectares) would be impacted. Major benthic and epibenthic organisms in these areas include isopods, amphipods, harpacticoids, clams (Mya, Macoma), mussels, chironomids, and marine worms. Many of these are major food items for other epibenthic or pelagic organisms which are common in or near the estuaries, such as dungeness crab, salmon juveniles, sandlance, and starry flounder.

Sedimentation should occur very rapidly, within a few hours, according to the data of Poling (1982). Turk and Risk (1981) observed the amphipod Corophium volutator being affected quite severely at sediment depths of 2.8 cm and sedimentation rates of 7.0 cm/month. The clam Macoma balthica tolerated burial in 2.4 cm sediment at a rate of 10.2 cm/month, but did experience some decline in population. Therefore, within a 1 hectare radius of the spill, effects would be significant, but beyond a 10-15 hectare radius, effects on benthos would be insignificant. In addition, a spill could affect the food chain by burial of upper sedge or grass, or lower intertidal eelgrass, which supply important organic input to the estuaries.

Another major impact could occur from high suspended sediment concentrations for a brief period (less than 12 hours). Suspended solids concentrations in the estuaries will be maintained briefly and occur at concentrations less than those that are lethal to juvenile chum salmon. Salo et al. (1979, Table 4-2) determined 8-hour LC50s of 56 and 49 g/l for chum salmon. Suspended sediment concentrations of 250 mg/l have been found to reduce feeding of certain estuary zooplankton species, and levels of 100-500 mg/l caused substantial reduction in phytoplankton primary product (Sherk et al. 1976). This suggests reduction in primary production and possible impact on zooplankton or benthic organisms.

Although the area is small, if inundation occurred during periods of high juvenile salmon abundance in the estuary (April and June), effects could be significant. High suspended sediment concentrations would not be lethal but areas inundated may supply important food during that period. Until an area is recolonized it would not be available for feeding to juvenile salmon, which rely heavily on the harpacticoid copepods and chironomids affected by burial. Some reduction of these organisms would occur outside the 1.0 hectare area but these impacts would be much less on salmon feeding outside this area.

Spills that occur in nearshore areas of the inner and middle basin of Boca de Quadra and Wilson Arm would have lesser impact than in estuaries. Depth of sediment in the 1.0 hectare area would range from 11.7 to 16.3 cm (Appendix G, Table 16-1). These likely would result in nearly complete mortalities for the area covered. The settling would occur mostly in the nearshore area (less than 100 ft deep) in inner Boca de Quadra, but much settling would occur in the deep benthic area in middle Boca de Quadra or Wilson Arm depending on location of the pipeline break. A wider variety of organisms are present in the nearshore area than in the estuary. In addition to those found in the estuary, many other benthic and epibenthic organisms such as barnacles, snails, chiton, limpets, seastars, seacucumbers, nudibranches, sponges, hydroids, and ascidians are common. Many species of attached macrophytic algae (e.g., Fucus, Laminaria) are also present. Important pelagic and demersal fish present in the nearshore area include juvenile salmon, rockfish, herring, sandlance, flatfish (e.g., starry and yellowfin flounder), staghorn sculpin, Dolly Varden, dogfish, and shiner perch. Dungeness crab and various pandalid shrimp are also common. Unlike the estuary, nearshore areas are less restrictive in size so impacts from tailings spills will be less extensive. Some loss of feeding area will occur for pelagic and epibenthic organisms. Again, if spills occur during peak juvenile salmon abundance periods, the effect may be significant. However, due to the higher abundance of fjord nearshore habitats, these effects would be less severe than in estuaries. Other predators that feed in these areas, such as juvenile herring and sandlance, may be displaced initially. Because of the small size of the area, impacts to organisms other than those directly buried and feeding salmon would be insignificant.

If spills occur in outer Wilson Arm or middle Boca de Quadra much of the burial will cover benthic organisms (greater than 100 ft deep). These include cumaceans, marine worms, amphipods, clams, and harpacticoids. Common invertebrates that reside and feed in deep benthic areas include tanner and dungeness crab, pandalid and crangonid shrimp, and pinchbag crab. Abundant fish include sculpins, pricklebacks, rockfish, walleye pollock, eelpouts, dogfish, and occasionally halibut. Impacts in this region would be insignificant because only a small area (less than 1.0 hectare) will be covered. Also, the deep benthic area is the largest habitat in these fjords and a small loss of habitat will have no measurable impact.

Spills in any area will also put suspended sediments into epipelagic and mesopelagic habitats. Some local reduction in primary production and feeding success of zooplankton will occur. But impacts in either area will be insignificant because of the rapid rate of dispersion (<12 hours), and because of the small area to be affected.

In fresh water, the effects of a tailings spill could be very significant because there is less area and water available for dilution. Suspended solids concentrations (e.g., 20-717 g/l) could be above concentrations acutely lethal (49-56 g/l) to juvenile chum salmon (Salo et al. 1980). Depths of tailings on the bottom could range from 4 to 16.8 cm, enough to cause high mortalities of any salmon and trout eggs, as well as benthic, fish-food organisms (Appendix G, Table 16-1).

With respect to the proposed project (Tunnel Creek mill with Wilson Arm tailings disposal), an expanded analysis involving three spill scenarios is provided below to determine the maximum vulnerability of salmon populations. If a rupture were to occur along the mill tailings pipeline, and if the spilled tailings escaped the engineered containment system described in Section B, then salmonid populations associated with three aquatic regions could receive significant impacts:

1. Tunnel Creek might receive spilled tailings if a pipeline break were to occur near it or the Tunnel Creek mill site, which would be about one-half to one mile upstream from the creek's mouth at Wilson Arm.

2. If the break were to occur near the mouth of Tunnel Creek, the southern end of the Wilson estuary could receive a large part of the spilled tailings.

3. If the rupture were along Wilson Arm closer to the tailings discharge point, portions of the Wilson Arm fjord might be affected.

The first impact scenario is accounted for in Table 16-1 using scenario number 7, which involves an uncontained spill into middle Tunnel Creek. In this case the lower reaches of the creek could be covered with a layer of tailings about 7 cm deep. If this were to happen during spawning, egg incubation, or hatching phases of the salmonid life cycle, then as many as 27,000 returning adults could be lost (see Table 3-10).

The second scenario involves an uncontained tailings spill into the Wilson estuary. The Wilson estuary is shallow and supports temporary residence and feeding of salmon fry that have hatched upstream in the Blossom and Wilson rivers and Tunnel Creek. There are no scenarios in Table 16-1 that account for tailings spills from Tunnel Creek directly into the Wilson estuary, mainly because most of these tailings would likely travel into the upper end of the Wilson fjord. However, it is reasonable to assume that scenario number 8 could apply to spills into the Wilson estuary. As such, about 1 hectare of the estuary would be covered by about 10 cm of tailings. This represents about 0.7 percent of the estuary's surface area, or about 140 hectares. Assuming the worst, that 0.7 percent of all salmon fry would be lost collectively from Wilson and Blossom rivers and Tunnel Creek as a result of an equivalent loss of rearing habitat, then about 12,000 returning adults might be lost (i.e., 0.7 percent of 1,666,812 adult salmon; see Table 3-10).

The third scenario has been accounted for in Table 16-1 under scenario numbers 8 and 9. Here, an uncontained spill from the disposal pipeline running along Wilson Arm could release mill tailings into intertidal and subtidal regions. Approximately 1 hectare would be covered by about 10 to 14 cm of tailings, and, in addition, the water column would temporarily contain from 6 to 14 g/l of suspended solids. As discussed above, this spill would cause only minor impacts to fish, benthos, and epibenthos. While it is possible that some losses in fish and prey organisms would occur, depending mostly on the timing and duration of the spill, accurate estimations of these losses are not possible. Salmonids and other fishes would have ample spatial opportunities to avoid the spilled tailings. Furthermore, the fraction of prey organisms potentially lost would not represent a significant percentage to dependent

fishes, given the localized distribution and rapid dilution of spilled tailings. This scenario, therefore, allows only an assumption that fish losses would be less than those expected from either of the first two scenarios (i.e., less than 12,000 returning adults).

The worst of these three scenarios is the first: 27,000 returning adult salmon could be lost if mill tailings spilled into Tunnel Creek during spawning or while salmon eggs were incubating or hatching. While this estimate is an expression of salmonid vulnerability, it does not indicate the likelihood of occurrence. The likelihood of spilled mill tailings entering salmonid habitats approaches zero, considering the risk analysis presented in Section B.

APPENDIX G, SECTION 17, TABLE 17-1a

ESTIMATED LOSSES OF FISH, SHELLFISH, AND HABITAT IN RELATION TO PROJECT COMPONENT AND ALTERNATIVE

						Average Loss per Occurrence				
						Number		Biomass (kg)		Area (Ac)
Alternative	Aquatic Environment	Project Component	Impact	Duration	Frequency	Salmon	Char and Trout	Bottom-fish	Shell-fish	Habitat
Tunnel Cr. Mill with inner basin Boca de Quadra tailings disposal and commute option	Beaver Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs a/	17 b/	6			
	Beaver Cr.	Water use and drainage alteration	Dewatering	1 year	once in 10 yrs	17 b/	6			
	Blossom R.	Access road	Sediment	1-2 years	intermittent	24,463 c/	141			
	Hill Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	138 b/	149			
	Wilson Arm	Access road	Habitat burial	project life	annually					1.7 h/
	Boca de Quadra inner basin and middle basin	Tailings disposal inner basin	Habitat burial	project life	annually			7070 f/	7490 f/	

a/ Probability of occurrence is once in 10 years.
b/ Breakdown by species in Appendix G, Table 4-1.
c/ Breakdown by species in Appendix G, Table 5-2.
d/ Breakdown by species in text Table 3-10.
e/ Breakdown by species in Appendix G, Table 5-3.
f/ Breakdown by species in text Table 4-13.
g/ Annual number rockfish caught by local sportsmen, not a true loss; cannot be estimated for all other organisms.
h/ Nearshore and estuary habitat.
i/ Upper estuary habitat.
j/ Nearshore fjord habitat, or fjord bottom depending on tailings line placement option.
k/ Estuary habitat.

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APPENDIX G, TABLE 17-1b

ESTIMATED LOSSES OF FISH, SHELLFISH, AND HABITAT IN RELATION TO PROJECT COMPONENT AND ALTERNATIVE

Alternative	Aquatic Environment	Project Component	Impact	Duration	Frequency	Average Loss per Occurrence: Number: Salmon	Number: Char and Trout	Biomass (kg): Bottom-fish	Biomass (kg): Shell-fish	Area (Ac): Habitat
Tunnel Cr. Mill with Boca de Quadra Tailings Disposal, Upper Hill Creek Diversion, and Townsites	Beaver Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	17 b/	6			
	Beaver Cr.	Water use and drainage alteration	Dewatering	1 year	once in 10 yrs	17 b/	6			
	Blossom R.	Access road	Sediment	1-2 years	intermittent	24,463 c/	141			
	Hill Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	138 b/	149			
	North Cr.	Upper Hill C. diversion	Channel alteration	3-4 years	annually	17 b/	2			
	All	Townsites	Increased sport fishing	project life	annually	Cannot be determined		30,000 g/		
	Wilson Arm	Access road	Habitat burial	project life	annually					1.7 h/
Option I	Boca de Quadra inner and middle basins	Tailings disposal inner	Habitat burial	project life	annually			7070 f/	7490 f/	
Option II	Boca de Quadra middle basin	Tailings disposal middle	Habitat burial	project life	annually			1190 f/	1500 f/	
Option III	Boca de Quadra inner and middle basins	Tailings disposal inner move to middle	Habitat burial and	project life	annually			2790 f/	2740 f/	
Option III	Boca de Quadra inner and middle basins	Subtidal tailings line	Habitat disturbance	1-6 months	4 months-3 years					4.0 j/

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APPENDIX G, TABLE 17-1c

ESTIMATED LOSSES OF FISH, SHELLFISH, AND HABITAT IN RELATION TO PROJECT COMPONENT AND ALTERNATIVE

Alternative	Aquatic Environment	Project Component	Impact	Duration	Frequency	Average Loss per Occurrence: Number: Salmon	Number: Char and Trout	Biomass (kg): Bottom-fish	Biomass (kg): Shell-fish	Area (Ac): Habitat
Tunnel Cr. Mill with Wilson Arm Tailings Disposal	Beaver Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	17 b/	6			
	Beaver Cr.	Water use and drainage	Dewatering	1 year	once in 10 yrs	17 b/	6			
	Blossom R.	Access road	Sediment	1-2 year	intermittent	24,463 c/	141			
	Hill Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	138 b/	149			
	Wilson Arm	Access road	Habitat burial	project life	annually					1.9 h/
	Wilson Arm/ Smeaton Bay/ Bakewell Arm	Tailings disposal	Habitat burial	project life	annually			4570 f/	9500 f/	

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APPENDIX G, TABLE 17-1d

ESTIMATED LOSSES OF FISH, SHELLFISH, AND HABITAT IN RELATION TO PROJECT COMPONENT AND ALTERNATIVE

						Average Loss per Occurrence				
						Number		Biomass (kg)		Area (Ac)
Alternative	Aquatic Environment	Project Component	Impact	Duration	Frequency	Salmon	Char and Trout	Bottom-fish	Shell-fish	Habitat
Beaver Cr. Mill with Boca de Quadra Tailings Disposal	Beaver Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	17 b/	6			
	Beaver Cr.	Water use and drainage alteration	Dewatering	1 year	once in 10 yrs	17 b/	6			
	Raspberry Cr	Reservoir	Dewatering	project life	annually	45 b/	29			
	Blossom R.	Access road	Sediment	1-2 years	intermittent	24,463 c/	141			
	Hill Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	138 b/	149			
	Wilson Arm	Access road	Habitat burial	project life	annually					1.7 h/
Option I	Boca de Quadra inner and middle basins	Tailings disposal inner	Habitat burial	project life	annually			7070 f/	7490 f/	
Option II	Boca de Quadra middle basin	Tailings disposal middle	Habitat burial	project life	annually			1690 f/	1500 f/	
Option III	Boca de Quadra inner and middle basins	Tailings disposal inner move to middle basin	Habitat burial	project life	annually			2790 f/	2740 f/	
Option II or III	Boca de Quadra middle and inner basins	Subtidal tailings line	Habitat disturbance	1-6 months	4 months-3 years					4.0 j/

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APPENDIX G, TABLE 17-1e

ESTIMATED LOSSES OF FISH, SHELLFISH, AND HABITAT IN RELATION TO PROJECT COMPONENT AND ALTERNATIVE

						Average Loss per Occurrence				
						Number		Biomass (kg)		Area (Ac)
Alternative	Aquatic Environment	Project Component	Impact	Duration	Frequency	Salmon	Char and Trout	Bottom-fish	Shell-fish	Habitat
Beaver Cr. Mill with Wilson Arm Tailings Disposal	Beaver Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	17 b/	6			
	Beaver Cr.	Water use and drainage alteration	Dewatering	1 year	once in 10 yrs	17 b/	6			
	Raspberry Cr	Reservoir	Dewatering	project life	annually	45 b/	29			
	Blossom R.	Access road	Sediment	1-2 years	intermittent	24,463 c/	141			
	Hill Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	138 b/	149			
	Wilson Arm	Access road	Habitat burial	project life	annually					2.7 h/
	Wilson Arm/ Smeaton Bay/ Bakewell Arm	Tailings disposal	Habitat burial	project life	annually			4570 f/	9500 f/	
	Wilson Arm	Subtidal tailings line	Habitat disturbance	1-6 months	4 months-3 years					3.4 j/

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APPENDIX G, TABLE 17-1f

ESTIMATED LOSSES OF FISH, SHELLFISH, AND HABITAT IN RELATION TO PROJECT COMPONENT AND ALTERNATIVE

						Average Loss per Occurrence				
						Number		Biomass (kg)		Area (Ac)
Alternative	Aquatic Environment	Project Component	Impact	Duration	Frequency	Salmon	Char and Trout	Bottom-fish	Shell-fish	Habitat
Beaver Cr. Mill with On-land Tailings Disposal	Beaver Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	17 b/	6			
	Beaver Cr.	Water use and drainage alteration	Dewatering	1 year	once in 10 yrs	17 b/	6			
	Raspberry Cr	Reservoir	Dewatering	project life	annually	45 b/	29			
	Blossom R.	Access road	Sediment	1-2 years	intermittent	24,463 c/	141			
	Hill Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	138 b/	149			
	Tunnel Cr.	Tailings disposal	Habitat burial, dewatering	project life	annually	27,397 d/	121			
	Aronitz Cr.	Tailings disposal	Habitat burial, dewatering	project life	annually	2860 d/	2			
	Wilson Arm	Access road	Habitat burial	project life	annually					1.7 h/

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APPENDIX G, TABLE 17-1g

ESTIMATED LOSSES OF FISH, SHELLFISH, AND HABITAT IN RELATION TO PROJECT COMPONENT AND ALTERNATIVE

Alternative	Aquatic Environment	Project Component	Impact	Duration	Frequency	Average Loss per Occurrence: Number: Salmon	Number: Char and Trout	Biomass (kg): Bottom-fish	Biomass (kg): Shell-fish	Area (Ac): Habitat
North Meadow Mill with Boca de Quadra Tailings Disposal	Beaver Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	17 b/	6			
	Beaver Cr.	Water use and drainage alteration	Dewatering	1 year	once in 10 yrs	17 b/	6			
	Hill Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	138 b/	149			
	Hill Cr.	Reservoir	Dewatering	15 yrs	annually	138 b/	149			
	Keta R.	Access road	Sediment	1-2 years	intermittent	38,539 e/	77			
	All	Keta townsite	Increased sport fishing	project life	annually	cannot be determined		30,000 g/		
	Boca de Quadra	Access road	Habitat burial	project life	annually					3.3 i/
	Boca de Quadra	Tailings line road	Habitat burial	project life	annually					3.4 k/
Option I	Boca de Quadra inner and middle basins	Tailings disposal inner	Habitat burial	project life	annually			7070 f/	7490 f/	
Option II	Boca de Quadra middle basin	Tailings disposal middle	Habitat burial	project life	annually			1690 f/	1500 f/	
Option III	Boca de Quadra middle and inner basins	Tailings disposal inner move middle	Habitat burial	project life	annually			2790 f/	2740 f/	

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APPENDIX G, TABLE 17-1g (Continued)

						Average Loss per Occurrence				
						Number		Biomass (kg)		Area (Ac)
Alternative	Aquatic Environment	Project Component	Impact	Duration	Frequency	Salmon	Char and Trout	Bottom-fish	Shell-fish	Habitat
Option I	Boca de Quadra inner basin	Subtidal tailings line	Habitat disturbance	1-6 months	4 months-3 years					2.0 L/
Option II or III	Boca de Quadra inner and middle basins	Subtidal tailings line	Habitat disturbance	1-6 months	4 months-3 years					6.0 L/

APPENDIX G, TABLE 17-1h

ESTIMATED LOSSES OF FISH, SHELLFISH, AND HABITAT IN RELATION TO PROJECT COMPONENT AND ALTERNATIVE

						Average Loss per Occurrence				
						Number		Biomass (kg)		Area (Ac)
Alternative	Aquatic Environment	Project Component	Impact	Duration	Frequency	Salmon	Char and Trout	Bottom-fish	Shell-fish	Habitat
North Meadow Mill with On-land Tailings Disposal	Beaver Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	17 b/	6			
	Beaver Cr.	Water use and drainage alteration	Dewatering	1 year	once in 10 yrs	17 b/	6			
	Blossom R.	Access road	Sediment	1-2 years	intermittent	24,463 c/	141			
	Hill Cr.	Sedimentation pond	Sediment	1 year	once in 10 yrs	138 b/	149			
	Hill Cr.	Reservoir	Dewatering	15 yrs	annually	138 b/	149			
	Tunnel Cr.	Tailings disposal	Habitat burial, dewatering	project life	annually	27,397 d/	121			
	Aronitz Cr.	Tailings disposal	Habitat burial, dewatering	project life	annually	2860 d/	2			
	Wilson Arm	Access road	Habitat burial	project life	annually					1.7h/

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APPENDIX G

SECTION 18

VALUES OF COMMERCIAL FISH AND SHELLFISH POTENTIALLY LOST

Assumptions made and procedures used in estimating the value of commercial fish and shellfish losses are as follows:

1. Only commercial losses were estimated. The value of fish from the sport fishery, such as Dolly Varden, is not included.

2. Estimates of commercial fish and biomass were taken from the following tables:

Species	Aquatic Environment	Reference Table
Salmon	Beaver Creek	App. G, Table 4-1[a/]
	Hill Creek	App. G, Table 4-1[a/]
	North Creek	App. G, Table 4-1[a/]
	Raspberry Creek	App. G, Table 4-1[a/]
	Aronitz Creek	Text Table 3-10
	Tunnel Creek	Text Table 3-10
	Blossom River	App. G, Table 5-2
	Keta River	App. G, Table 5-3
Bottomfish	Boca de Quadra inner and middle basins, Wilson Arm, Smeaton Bay, Bakewell Arm	Text Table 4-12[b/]
Shellfish	Boca de Quadra inner and middle basins, Wilson Arm, Smeaton Bay, Bakewell Arm	Text Table 4-12[b/]

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a/ Commercial loss equals 80 percent of total adult loss of coho and chinook salmon shown on the table. This is comparable to the commercial harvest percentage shown in Appendix G, Tables 5-2 and 5-3.

b/ Commercial loss was assumed to be 20 percent of standing stock. This value was based on harvest rates of other marine species in this area. Herring harvest rate is 10 percent (Blankenbeckler and Larson 1982b). Rockfish harvest rate in the Queen Charlotte Islands is recommended to be 5-10 percent (Archibald et al. 1983). These values were doubled to conservatively allow for differences between species.

3. Annual probabilities of loss were estimated from frequency of damaging occurrences such as dewatering, siltation, or habitat burial as shown in Appendix G, Tables 17-1a through 17-1h. A frequency of one occurrence in 10 years, for example, equals an annual probability of 0.10.

4. The expected annual loss by species equals the loss per damaging occurrence times the annual probability of occurrence.

5. Annual losses in number of fish or kilograms of biomass were converted to loss in pounds using the following conversion factors:

Species	Conversion
Chinook salmon	14 lbs/fish (ADF&G 1979)
Coho salmon	8 lbs/fish (ADF&G 1979)
Chum salmon	10 lbs/fish (ADF&G 1979)
Pink salmon	3.5 lbs/fish (ADF&G 1979)
Bottomfish and shellfish	1 kg = 2.2046 lbs

6. Prices per pound by species were calculated from average exvessel prices (Koeneman 1983b, 1983c; Blankenbeckler and Larson 1982b). Salmon, bottomfish, and shellfish prices for fisheries management districts 5-10, years 1980 through 1982, were averaged and updated to 1984 dollars. Salmon prices represent a weighted average by species and gear type for purse seine, drift gill net, and troll (ADF&G 1979).

7. Total value of commercial fishery losses in each aquatic environment (Appendix G, Table 18-1) was calculated as the annual loss in pounds times the price per pound.

8. Total value of commercial fishery losses for each tailings disposal method (Appendix G, Table 18-2) was calculated as the sum of the aquatic environments affected. The environments affected by each disposal alternative are given in Appendix G, Tables 17-1a through 17-1h, while the value of losses for each is given in Appendix G, Table 18-2.

TABLE 18-1

MAXIMUM ANNUAL VALUE OF COMMERCIAL FISH AND SHELLFISH LOSSES, BY AQUATIC ENVIRONMENT

Species	Avg. Comm. Loss per Occurrence (Number)	Annual Probability[a/]	Annual Loss (Number)	Annual Loss[b/] (lbs)	Price/ lb[c/] (1984 $)	Annual Value (1984 $)
SALMON[d/]						
Beaver Creek						
Chinook	-	.20	-	-	2.42	-
Coho	14 [e/]	.20	2.8	22.4	1.30	29
Chum	-	.20	-	-	.64	-
Pink	-	.20	-	-	.43	-
						29
Blossom River						
Chinook	231 [a/]	.10	23.1	323.4	2.42	783
Coho	598 [g/]	.10	59.8	478.4	1.30	622
Chum	333 [g/]	.10	33.3	333.0	.64	213
Pink	15,351 [g/]	.10	1,535.1	5,372.9	.43	2,310
						3,928
Hill Creek						
Chinook	27 [e/]	.10	2.7	37.8	2.42	91
Coho	83 [e/]	.10	8.3	66.4	1.30	86
Chum	-	.10	-	-	.64	-
Pink	-	.10	-	-	.43	-
						177
North Creek						
Chinook	1 [e/]	1.0	1	14	2.42	34
Coho	13 [e/]	1.0	13	104.0	1.30	135
Chum	-	1.0	-	-	.64	-
Pink	-	1.0	-	-	.43	-
						169
Raspberry Creek						
Chinook	8 [e/]	1.0	8	112.0	2.42	271
Coho	28 [e/]	1.0	28	224.0	1.30	291
Chum	-	1.0	-	-	.64	-
Pink	-	1.0	-	-	.43	-
						562

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TABLE 18-1 (Continued)

Species	Avg. Comm. Loss per Occurrence (Number)	Annual Probability[a]	Annual Loss (Number)	Annual Loss[b] (lbs)	Price lb[c] (1983 $)	Annual Value (1983 $)
SALMON (Con't)						
Tunnel Creek						
Chinook	23 [f]	1.0	23	322.0	2.42	799
Coho	133 [f]	1.0	133	1,064.0	1.30	1,383
Chum	1,069 [f]	1.0	1,069	10,690.0	.64	6,842
Pink	17,123 [f]	1.0	17,123	59,930.5	.43	25,770
						34,774
Aronitz Creek						
Chinook	1 [f]	1.0	1	14.0	2.42	34
Coho	13 [f]	1.0	13	104.0	1.30	135
Chum	445 [f]	1.0	445	4,450.0	.64	2,848
Pink	1,445 [f]	1.0	1,445	5,057.5	.43	2,175
						5,192
Keta River						
Chinook	477 [h]	.10	47.7	667.8	2.42	1,616
Coho	590 [h]	.10	59.0	472.0	1.30	614
Chum	6,590 [h]	.10	659.0	6,590.0	.64	4,218
Pink	18,186 [h]	.10	1,818.6	6,365.1	.43	2,737
						9,185
BOTTOMFISH	(kg)					
Boca de Quadra Inner and Middle Basins						
Option I						
Pollock	358[j]	1.0		789	.25	197
Rockfish	102[j]	1.0		225	.37	83
Flatfish	954[j]	1.0		2,103	.26	547
						827

TABLE 18-1 (Continued)

Species	Avg. Comm. Loss per Occurrence (number)	Annual Probability[a]	Annual Loss (Number)	Annual Loss[b] (lbs)	Price/ lb[c] (1983 $)	Annual Value (1983 $)
BOTTOMFISH (Continued)						
Option II						
Pollock	164	1.0		362	.25	91
Rockfish	112	1.0		247	.37	91
Flatfish	62	1.0		137	.26	36
						218
Boca de Quadra Inner and Middle Basins (Continued)						
Option III						
Pollock	186	1.0		410	.25	103
Rockfish	94	1.0		207	.37	77
Flatfish	278	1.0		613	.26	159
						339
Wilson Arm/ Smeaton Bay/ Bakewell Arm						
Pollock	120	1.0		265	.25	66
Rockfish	4	1.0		9	.37	3
Flatfish	790	1.0		1,742	.26	453
						522
SHELLFISH[j]	(kg)					
Boca de Quadra Inner and Middle Basins						
Option I						
Dungeness crab	326	1.0		719	.67	482
Tanner crab	112	1.0		247	.95	235
Pot shrimp	148	1.0		326	3.55	1,158
Trawl shrimp	912	1.0		2,011	.26	523
						2,398
Option II						
Dungeness crab	82	1.0		181	.67	121
Tanner crab	50	1.0		110	.95	105
Pot shrimp	22	1.0		49	3.55	174
Trawl shrimp	146	1.0		322	.26	84
						484

TABLE 18-1 (Continued)

Species	Avg. Comm. Loss per Occurrence	Annual Probability[a/]	Annual Loss (Number)	Annual Loss[b/] (lbs)	Price/ lb[c/] (1983 $)	Annual Value (1983 $)
SHELLFISH (Continued)						
Boca de Quadra Inner and Middle Basins (Continued)						
Option III						
Dungeness crab	132	1.0		291	.67	195
Tanner crab	54	1.0		119	.95	113
Pot shrimp	50	1.0		110	3.55	391
Trawl shrimp	312	1.0		688	.26	179
						878
Wilson Arm/ Smeaton Bay/ Bakewell Arm						
Dungeness crab	192	1.0		423	.67	283
Tanner crab	472	1.0		1,041	.95	989
Pot shrimp	96	1.0		212	3.55	753
Trawl shrimp	1,140	1.0		2,513	.26	653
						2,678

a/ Frequency of occurrence given in Appendix G, Table 17-1.
b/ Average salmon weights by species are: chinook - 14 pounds; coho - 8 pounds; chum - 10 pounds; pink - 3.5 pounds.
c/ Prices based on weighted average exvessel price by species and method of catch (Koeneman 1983b and c; and Blankenbeckler 1982) updated to 1984 dollars.
d/ Salmon value does not include sport fishing value of chinook and other species.
e/ Commercial loss equals 80 percent of total adult loss shown in Appendix G, Table 4-1.
f/ Commercial loss by species from text Table 3-10.
g/ Commercial loss by species from Appendix G, Table 5-2.
h/ Commercial loss by species from Appendix G, Table 5-3.
i/ One kilogram = 2.2046 pounds.
j/ Bottomfish and shellfish commercial loss equals 20 percent of biomass in kg loss by species shown in text Table 4-12.

APPENDIX G

TABLE 18-2

ESTIMATED MAXIMUM ANNUAL VALUE OF COMMERCIAL FISH AND SHELLFISH LOSSES, BY ALTERNATIVE

Alternative	Option[b/]	Value of Losses ($)[a/]			
		Salmon	Bottom-fish	Shell-fish	Total
Tunnel Cr. Mill with Boca de Quadra Tailings Disposal and Commute Option	I	4,134	827	2,398	7,359
Tunnel Cr. Mill with Boca de Quadra Tailings Disposal, Upper Hill Creek Diversion, and Townsites	I	4,303	827	2,398	7,528
	II	4,303	218	484	5,005
	III	4,303	339	878	5,520
Tunnel Cr. Mill with Wilson Arm Tailings Disposal (the Proposed Project)		4,134	522	2,678	7,334
Beaver Cr. Mill with Boca de Quadra Tailings Disposal	I	4,696	827	2,398	7,921
	II	4,696	218	484	5,398
	III	4,696	339	878	5,913
Beaver Cr. Mill with Wilson Arm Tailings Disposal		4,696	522	2,678	7,896
Beaver Cr. Mill with On-Land Tailings Disposal		44,662	-	-	44,662
North Meadow Mill with Boca de Quadra Tailings Disposal	I	9,391	827	2,398	12,616
	II	9,391	218	484	10,093
	III	9,391	339	878	10,608
North Meadow Mill with On-Land Tailings Disposal		44,100	-	-	44,100

a/ All values equal the sum of values for aquatic environments affected. Values by species and environment are shown in Appendix G, Table 18-1. Environments affected by each alternative are shown in Appendix G, Tables 17-1a through 17-1h.
b/ See Appendix G, Table 17-1b.

APPENDIX H
VEGETATION & WILDLIFE

APPENDIX H

VEGETATION AND WILDLIFE

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APPENDIX H

TABLE H-1

VEGETATION SUBTYPES AT POTENTIAL FACILITY LOCATIONS
IN THE QUARTZ HILL PROJECT AREA[a/]

Potential Facility Locations	Vegetation Subtypes[b/] WDF	PDF	DF	OF	HM	FM	SF	SM	LEM	HEM	RL	RH	AC	FW
Quartz Hill/White Creek	D[c/]	D		M	M	S	D	S				M	M	
Middle Hill Creek Valley	S	D			M	M	M					S	M	
Beaver Creek Valley	S	D		M	M	S	S					M	S	S
Bruce's Nose	S	S				D	S					M		M
Tunnel Creek Valley	D	D		M	M	M					S	M	M	
Blossom Access Road Corridor														
Tidelands Segment	M	D							M	M	M			M
Sidehill Segment	D	S				M					M	M		
Beaver Creek Segment	M	D		M	M	M						M	M	S
Fuel Cache		S			D									
Wilson Estuary[d/]	M	M							D	D	M			M
Wilson Townsite	S	D												
Blossom River Valley	D	D	M		M						S			M
Keta River Valley	D	D	M		M					M	S		M	M
Keta Estuary[e/]	M	M							D	D	M			
Aronitz Creek Valley	D	D		M	M	M					S	M	S	M
Bakewell Townsite		D	M		D	M			M		M			M
Bakewell Estuary[f/]									D	S	M			
Falsegate Creek Valley	D	D			M	M					M	M	M	

a/ From U.S. Borax 1983a, Table 7-13.

b/ WDF - Well-drained forest
PDF - Poorly-drained forest
DF - Deciduous forest
OF - Open forest
HM - Herbaceous muskeg
FM - Forested muskeg
SF - Subalpine forest
SM - Subalpine meadow
LEM - Low estuarine marsh
HEM - High estuarine marsh
RL - Riparian low elevation
RH - Riparian high elevation
AC - Avalanche chute scrub
FW - Freshwater marsh

c/ D - Dominant vegetation subtype (in areal extent)
S - Subdominant vegetation subtype
M - Minor vegetation subtype

d/ Includes Tunnel Creek Estuary
e/ Includes Aronitz Creek Estuary
f/ Includes Falsegate Creek Estuary

APPENDIX H

TABLE H-2

RARE PLANT SPECIES WHICH COULD OCCUR IN THE QUARTZ HILL AREA a/

Family	Genus	Species	Common Name	Status b/	Habitat
Campanulaceae	Campanula	scouleri	Scouler harebell	3	Woods
Cruciferae	Cardamine	angulata	Seaside bittercress	3	Moist, shaded areas
Cyperaceae	Carex	plectocarpa (eleusinoides)	Goose-grass sedge	1, 2	Sandbars
Gramineae	Calamagrostis	crassiglumis	Thickglume reedgrass	1, 2	Brackish swales, meadows
	Danthonia	spicata var. pinetorum	Poverty oatgrass	3	Dry areas
	Glyceria	leptostachya	Davy mannagrass	2, 3	Pond and lake margins
	Melica	subulata	Alaska oniongrass	3	Meadows and woods
	Poa	laxiflora	Loose-flowered bluegrass	1, 2	Open meadows along streams (Behm Canal)
Hymenophyllaceae	Mecodium	wrightii	None	2	Wet maritime areas on rocks, tree trunks, among mosses
Labiatae	Stachys	mexicana (emersonii)	Ciliate hedge-nettle	3	Moist areas
Leguminosae	Lathyrus	venosus var. intonsus	None	3	Woods and thickets
	Lupinus	lepidus	None	3	Hillsides and open woods
Nymphaeaceae	Brasenia	schreberi	Watershield	3	Ponds
Ophioglossaceae	Botrychium	virginianum	Rattlesnake fern	3	Ponds

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TABLE H-2 (Continued)

Family	Genus	Species	Common Name	Status b/	Habitat
Orchidaceae	Cypripedium	montanum	Mountain lady's-slipper	1	Open woods
	Cypripedium	calceolus var. parviflorum	Lady's slipper	2	Open woods
	Malaxis	paludosa	Bog adders-tongue	2	Marshes, bogs
	Platananthera (Habenaria)	chorisiana	Choris bog-orchid	2	Sphagnum bogs
	Platananthera (Habenaria)	orbiculata	Round-leaved bog-orchid	2	Woods
	Platananthera (Habenaria)	unalascensis	Alaska bog-orchid	2	Marshes, bogs
Polypodiaceae	Asplenium	trichomanes	Maidenhair spleenwort	2	Rock outcrops, talus slopes
Pyrolaceae	Chimaphila	umbellata var. occidentalis	Pipsissewa	3	Coastal woodlands
	Monotropa	uniflora	Indian-pipe	3	Coastal woodlands
Rosaceae	Crataegus	douglasii	Black hawthorn	3	Woods
	Physocarpus	capitatus	Pacific ninebark	3	Woods
Rubiaceae	Galium	kamtschaticum	Northern wild-licorice	2	Moist, mossy areas
Scrophulariaceae	Penstemon	serrulatus	None	3	Moist areas
Violaceae	Viola	sempervirens	None	3	Forests

a/ Source: VTN 1982k, Table 1-1.

b/ 1 - Listed as taxa currently under review by the U.S. Fish and Wildlife Service (USFWS) (Fed. Reg., Dec. 15, 1981).
2 - Considered rare by the Tongass National Forest (Muller 1981).
3 - Plant species at the northern or southern extent of their known distribution.

APPENDIX H

TABLE H-3

SUMMARY OF SURVEYS FOR BALD EAGLE NESTS ON MAJOR ISLANDS AND MAINLAND COAST OF SOUTHEAST ALASKA, 1969-1979[a]

Island	Approx. Miles of Shoreline	Miles of Nest Surveys	Nests Found	Nests Per Mile
Admiralty	860	860	901	1.05
Baranof	920	163	158	.97
Chichagof	1100	484	428	.88
Etolin	190	164	107	.65
Kosciusko	155	95	71	.75
Kruzof	130	10	2	.20
Kuiu	640	159	145	.91
Kupreanof	460	175	125	.71
Mitkof	120	61	32	.52
Prince of Wales	1470	457	272	.60
Revillagigedo	420	193	76	.39
Wrangell	130	107	48	.45
Zarembo	63	63	39	.62
Mainland Coast	3200	632	505	.80
Total	9858	3623	2909	.80

a/ From Hodges and Robards 1982.

APPENDIX H

TABLE H-4

MOUNTAIN GOAT HARVEST IN THE SMEATON BAY-
BOCA DE QUADRA AREA 1980-1983[a/]

Year	Kill Within K-4 Survey Area[b/]	Number of Hunters/ Hunter-Days in K-4 Survey Area	Kill Within Adjacent Area[c/]	Number of Hunters/ Hunter Days in Adjacent Area[c/]
1980	2	5/11	7	10/23
1981	4	6/12	4	11/30
1982	0	0/0	6	11/33
1983[d/]	3	3/6	6	9/44

a/ Source: Smith 1983c.

b/ See Figure 3-19 for boundaries of the K-4 area.

c/ Wilson River, Blossom River, and Boca de Quadra, side unknown.

d/ Season not completed at time of compilation.

APPENDIX H

TABLE H-5

BLACK BEAR HARVEST IN THE SMEATON BAY-BOCA DE QUADRA AREA 1974-1983[a/]

Year	Season	Bears Killed In Smeaton Drainage	Number and Location	Bears Killed In Boca de Quadra Drainage	Number and Location
1974	Spring	5	3 Unknown 2 Wilson Arm[b/]	6	3 Marten Arm 2 Keta River[b/] 1 Mink Arm
	Fall	0		4	2 Humpback Lake 1 Hugh Smith Lake 1 Marten Arm
1975	Spring	3	1 Wilson Arm[b/] 2 Bakewell Arm[b/]	6	1 Vixen Bay 2 Marten Arm 2 Keta River[b/] 1 Badger Lake
	Fall	0	(Plus 2 killed in defense of life and property (DLP) by U.S. Borax)[b/]	1	1 Humpback Lake
1976	Spring	3	3 Unknown (Plus 1 DLP by U.S. Borax)[b/]	3	1 Unknown 1 Marten Arm 1 Mink Arm
	Fall	1	1 Bakewell Arm[b/]	0	
1977	Spring	0	(Plus 1 DLP by U.S. Borax)[b/]	0	
	Fall	0		0	
1978	Spring	0	(Plus 1 DLP by Amaco)[b/]	0	
	Fall	0		0	
1979	Spring	3	3 Unknown (Plus 1 DLP by U.S. Borax)[b/]	0	
	Fall	0		0	
1980	Spring	5	1 Skull Creek 2 Wilson Arm[b/] 1 Bakewell Arm[b/]	2	1 Badger Lake 1 Vixen Arm
	Fall	0		4	2 Marten Arm 2 Hugh Smith Lake

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TABLE H-5 (Continued)

Year	Season	Bears Killed In Smeaton Drainage	Number and Location	Bears Killed In Boca de Quadra Drainage	Number and Location
1981	Spring	3	2 Unknown 1 Bakewell Arm[b/]	3	2 Humpback Lake 1 Hugh Smith Lake
	Fall	0		1	1 Marten Arm
1982	Spring	0		2	2 Marten Arm
	Fall	3	3 Bakewell Arm[b/]	3	1 Humpback Lake 2 Marten Arm
1983	Spring	2	2 Cabin Creek	0	
(up to 1 Nov.)	Fall	0		4	4 Hugh Smith Lake

a/ Source: Wood 1983b.

b/ Considered to be within the Quartz Hill project area.

APPENDIX H

TABLE H-6

BROWN BEAR HARVEST IN THE SMEATON BAY-
BOCA DE QUADRA AREA 1961-1983[a/]

Year	Number of Bears Killed	Location
1961-1979	No brown bear kills reported	
1980	1	Marten Arm
1981	0	
1982	0	
1983	1	Wilson Arm

a/ Source: Wood 1983b.

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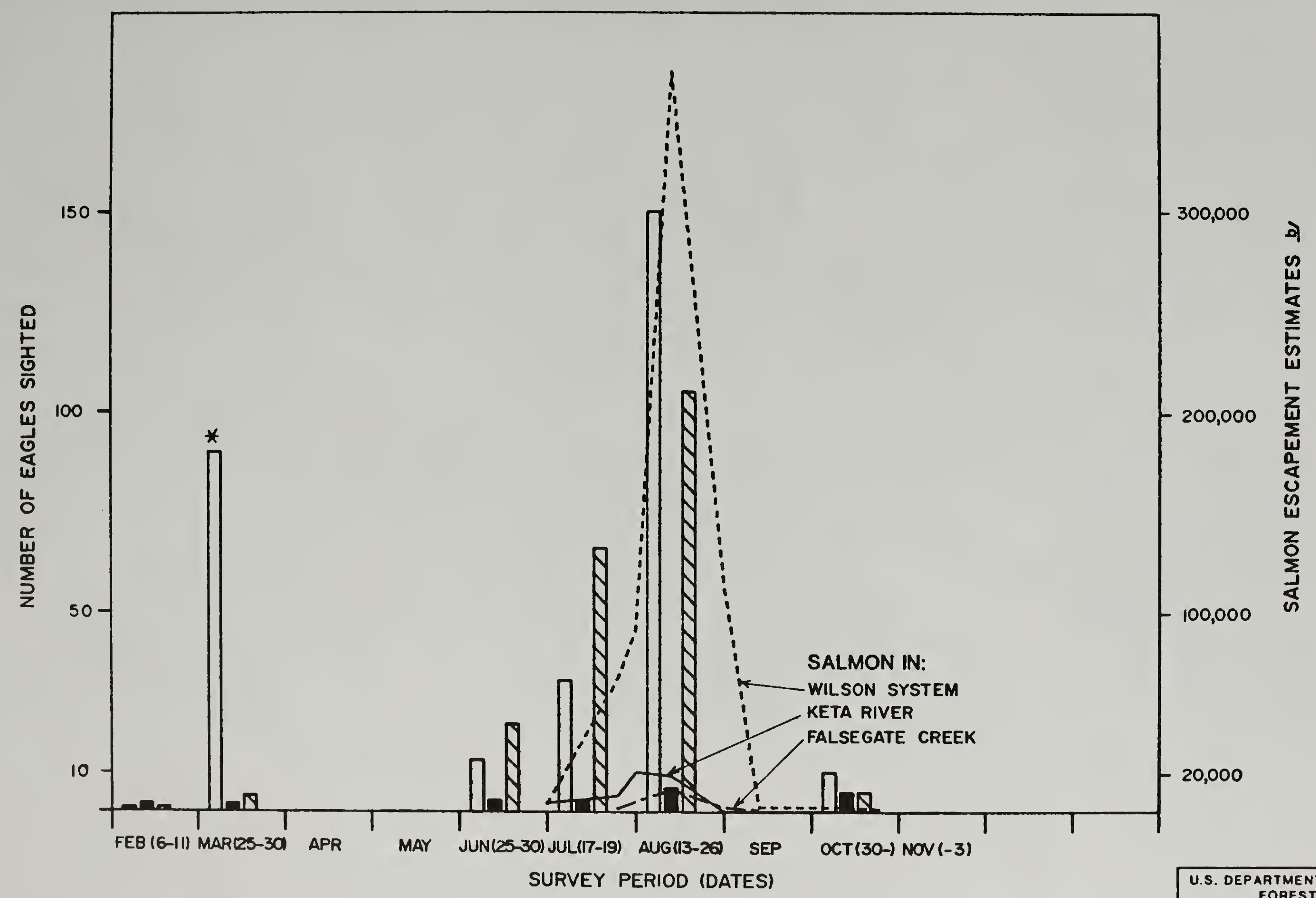

a/ ADAPTED FROM VTN 1982d, TABLE 2-11
b/ FROM VTN 1982 F
* SMELT (EULACHON) RUN IN THE WILSON RIVER SYSTEM

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

SUMMARY OF BALD EAGLE SIGHTINGS
QUARTZ HILLS PROJECT AREA

SOURCE ENVIROSPHERE (1983) DATE DEC 83

FIGURE
H-1

envirosphere company

APPENDIX I
SOCIOECONOMICS

APPENDIX I

SOCIOECONOMICS

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APPENDIX I

SOCIOECONOMICS

The project-related forecasts of population, employment, housing, and school enrollment for the Ketchikan Gateway Borough (KGB) are presented in detail in this appendix. A separate forecast is provided for each of four development options: commute (Tables I-1A and I-1B), townsite (Tables I-2A and I-2B), phase-in townsite (Tables I-3A and I-3B), and temporary shutdown (Tables I-4A and I-4B). A fifth forecast (Tables I-5A and I-5B) represents a sensitivity test for the commute option, assuming a high rate of local hire. This appendix includes descriptions and data sources for all assumptions (Tables I-6 and I-7) and all equations (Tables I-8 and I-9) used in the forecast. Supporting information on where the project-related population will live is provided in Table I-10. The work force requirements on an annual basis for each development option are provided in Table I-11.

The forecasts are based on existing conditions in Ketchikan and on project related impacts of large-scale projects, including mining operations. Although one cannot predict with certainty, these forecasts are based on the assumption that the impacts associated with the Quartz Hill development would tend to be similar to the impacts of these other large scale projects. All forecasts are made in the assumed absence of major policy changes or actions by the city, borough, or state governments, or other groups. The number of speculative in-migrants, for example, could be affected by the amount of publicity the project receives and people's perception of job availability. The distribution of housing type could be affected by zoning ordinances, major private developments, or other changes that have not been predicted.

Baseline Employment and Population

Population and employment figures for the Ketchikan Gateway Borough in 1983 were provided by the Borough Planning Department. The baseline non-agricultural employment forecast assumes a constant annual growth rate of 1.28 percent through 2003. No growth is forecast thereafter. The baseline population forecast assumes the 1983 ratio of population to non-agricultural employment of 245 would remain unchanged.

Project-Induced Employment

Direct project-induced employment estimates were provided by U.S. Borax for construction workers, operations workers, and Ketchikan office employees. Quarterly estimates were made for 1985 through 1989, with annual estimates thereafter. The ratio of secondary employment to direct employment is assumed to be 0.25 for construction workers and 0.70 for operations and Ketchikan office workers (Leistritz et al. 1982).

Quartz Hill employees fall into three source categories: local, in-migrants, and in-migrant spouses. Working spouses of in-migrating workers are counted separately to avoid overestimating the population change associated with new workers. The ratio of local workers to in-migrants and in-migrant spouses varies by job classification. Ratios are based on experience with similar projects elsewhere. Ratios and data sources are detailed in Table I-6. The Commute Sensitivity Test 1 (Table I-5A) indicates the change in the employment and population estimates of the commute option (Table I-1A), which takes place when the local hire rate for construction is increased from 10 percent to 35 percent.

An estimate of total jobs filled includes not only direct and secondary employment, but also new openings created when employed local workers leave their current jobs to take a direct or secondary project-related job. These vacated local jobs represent employment opportunities for others, although they do not add to the total count of non-agricultural employment. The vacated local jobs estimated here represent the first round of a filtering process in which local people obtain better jobs with the project and new job openings are created as a result.

Project-Induced Population

The project-induced population is based on the number of in-migrating workers, the number who are expected to bring families with them, and the average size of the family. The assumptions made in this forecast are detailed in Table I-6, and the equations used to calculate population impacts are shown on Table I-8. Total population (without taking account of speculative in-migrants) is the sum of the baseline population plus project-induced population.

There are some people, termed speculative in-migrants, who would arrive in Ketchikan looking for work but who would be unsuccessful. It is not clear how many people that could be, or how long they would stay in the area. Many people who are unable to find work directly on the project would take secondary jobs or jobs vacated by locals going to take work on the project. The speculative in-migrants are only those who fail to find any job at all. An estimate of 10 percent of project-related jobs, plus families of these in-migrants, are estimated here. The speculative in-migrant population is not used in further calculations of housing and school age population because of the uncertain nature of their tenure in Ketchikan.

Baseline Housing Type and School Age Children

Baseline housing type is shown on Tables I-1B through I-5B. The baseline housing type forecast is based on information provided by the Ketchikan Gateway Borough Planning Department. The percentage of single family, multi-family, and mobile dwellings is projected to remain the same throughout the forecast period. Average household size, which determines the number of housing units required, is also projected to remain the same at 2.82 persons per household.

The baseline number of school age children, measured in terms of average daily membership, is assumed to be 0.46 children per household, as it was in 1983.

Residence of Project-Induced Population

The residence of project-induced population varies somewhat by scenario. Construction workers and their working spouses always live at the site, while their families live in Ketchikan or elsewhere in the borough. Ketchikan office workers and their families always live in Ketchikan. In the commute and temporary shutdown options, operations and secondary workers and their families also live in Ketchikan. Those filling vacated local jobs always live in Ketchikan.

The rate at which operations and secondary workers and their families move from Ketchikan to the Quartz Hill site in the townsite and phase-in townsite options is outlined in Table I-10. The operations population is assumed to shift gradually in the phase-in option as opposed to all at once in the townsite option. The secondary work force is assumed to shift over to the site gradually in both options. The secondary population is split between Ketchikan and the Quartz Hill site.

Housing Type in Ketchikan and the Borough

The percentage distribution of housing types is expected to change slightly due to the project, as outlined in Table I-8. Single family dwellings are expected to change from 70 percent of the baseline total to 60 percent during the construction phase and 65 percent in the operations phase. Multi-family dwellings would shift from 23 percent to 30 percent to 25 percent over the same period. Mobile dwellings are increased slightly from 7 percent without the project to 10 percent with the project. Total housing units are based on average household size and the project-induced population living in Ketchikan and the rest of the borough. It does not include housing for those living at the Quartz Hill site.

School Age Children in Ketchikan and the Borough

The number of project-induced school age children is based on the project-induced population living in Ketchikan, their average family size, and the number of school age children per family. The estimate does not include children at the Quartz Hill site. Assumptions about family size and children per family are given on Table I-7, while the equations used are given on Table I-9. The estimates presented here may be high by about 10 percent because the calculation is based on family size rather than household size and on children per family rather than children per household. It therefore assumes that some of the single persons have children. Average household size includes single persons living alone or with roommates, while average family size does not. The estimate of school age children could also be high if the percentage of workers bringing in their families or the average family size is smaller than what was assumed for these calculations.

TABLE I-1A

KETCHIKAN-GATEWAY BOROUGH
EMPLOYMENT AND POPULATION FORECAST
COMMUTE OPTION

MULTIPLIERS AND FACTORS USED IN THESE CALCULATIONS

GROBASEMP=	.0120	SPSOPER=	.15	IMMVAC=	.55
POPEMULT=	2.45	LOCKO=	.30	SPSVAC=	.15
SECMULTC=	.25	IMMKO=	.55	POPPCON=	.23
SECMULTO=	.70	SPSKO	.15	POPPOPR=	1.73
LOCCON=	.10	LOCSEC=	.30	POPPKO=	1.73
IMMCON=	.85	IMMSEC=	.50	POPPSEC=	1.52
SPSCON=	.05	SPSSEC=	.20	POPPVAC=	1.52
LOCOPER=	.30	LOCLV=	.55	SPECIMM=	.10
IMMOPER=	.55	LOCVAC=	.30	POPSPEC=	1.52

ITEM DESCRIPTION	1983	1984	1985				1986				1987				1988			
QTR			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
BASELINE																		
BASELINE NON-AG EMP	5937	6013	6090	6090	6090	6090	6168	6168	6168	6168	6247	6247	6247	6247	6327	6327	6327	6327
BASELINE POPULATION	14551	14732	14920	14920	14920	14920	15111	15111	15111	15111	15305	15305	15305	15305	15501	15501	15501	15501
PROJECT EMPLOYMENT																		
CONSTRUCTION EMPLOYMENT	0	0	0	0	0	80	80	90	200	400	830	1060	1150	1180	1160	1020	690	140
OPERATIONS EMPLOYMENT	0	0	0	0	0	0	0	0	0	0	10	70	90	90	90	130	180	380
KETCHIKAN OFFICE EMPLMNT	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	30
SECONDARY EMPLOYMENT	0	0	0	0	0	20	20	30	57	127	222	321	358	365	360	352	306	322
TOTAL PROJ RLTD EMPLMNT	0	0	0	0	0	100	100	130	267	617	1072	1461	1608	1645	1620	1512	1186	872
TOT NON-AG EMPLOYMENT	5937	6013	6090	6090	6090	6190	6268	6297	6435	6785	7318	7708	7854	7892	7947	7840	7512	7199
SOURCE OF EMPLOYEES																		
CONSTRUCTION																		
LOCAL	0	0	0	0	0	8	8	9	20	48	83	106	115	118	116	102	69	14
IMMIGRANT WORKER	0	0	0	0	0	68	68	77	170	408	706	901	978	1003	986	867	587	119
IMMIGRANT SPOUSE	0	0	0	0	0	4	4	5	10	24	42	53	58	59	58	51	35	7
OPERATIONS																		
LOCAL	0	0	0	0	0	0	0	0	0	0	3	21	27	27	27	39	54	114
IMMIGRANT WORKER	0	0	0	0	0	0	0	0	0	0	6	39	50	50	50	72	99	209
IMMIGRANT SPOUSE	0	0	0	0	0	0	0	0	0	0	2	11	14	14	14	20	27	57
KETCHIKAN OFFICE																		
LOCAL	0	0	0	0	0	0	0	3	3	3	3	3	3	3	3	3	3	9
IMMIGRANT WORKER	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	6	6	17
IMMIGRANT SPOUSE	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	5
SECONDARY JOBS																		
LOCAL	0	0	0	0	0	6	6	9	17	38	66	96	107	110	108	106	92	97
IMMIGRANT WORKER	0	0	0	0	0	10	10	15	29	64	111	161	179	183	180	177	153	161
IMMIGRANT SPOUSE	0	0	0	0	0	4	4	6	11	25	44	64	72	73	72	71	61	64
VACATED LOCAL JOBS																		
LOCAL	0	0	0	0	0	2	2	3	7	15	26	37	42	42	42	41	36	39
IMMIGRANT WORKER	0	0	0	0	0	4	4	6	12	27	47	68	76	78	77	76	66	71
IMMIGRANT SPOUSE	0	0	0	0	0	1	1	2	3	7	13	19	21	21	21	21	18	19
TOTAL JOBS FILLED																		
LOCAL	0	0	0	0	0	16	16	24	47	104	181	264	294	300	296	291	254	272
IMMIGRANT WORKER	0	0	0	0	0	82	82	103	216	504	874	1174	1288	1310	1298	1196	910	576
IMMIGRANT SPOUSE	0	0	0	0	0	9	9	14	26	58	102	140	165	168	166	162	142	152
TOTAL	0	0	0	0	0	108	108	141	289	666	1157	1585	1746	1787	1760	1650	1305	1000
PROJECT INDUCED POPULATION																		
TOTAL CONSTR POPULATION	0	0	0	0	0	84	84	94	209	502	868	1108	1202	1234	1213	1066	721	146
OPERATIONS POPULATION	0	0	0	0	0	0	0	0	0	0	15	105	135	135	135	195	270	579
KETCHIKAN OFFICE POP	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	45
SECONDARY POPULATION	0	0	0	0	0	25	25	37	72	160	279	404	450	460	453	444	385	405
VACATED JOB POPULATION	0	0	0	0	0	11	11	16	31	68	118	172	192	196	193	190	166	178
TOTAL PROJ INDUCED POP	0	0	0	0	0	119	119	162	326	745	1295	1805	1994	2039	2009	1911	1557	1344
TOTAL POP W/OUT SPEC	14551	14732	14920	14920	14920	15040	15231	15273	15438	15856	16600	17109	17299	17344	17510	17412	17057	16845
SPECULATIVE IMMIGRANTS	0	0	0	0	0	25	25	33	67	155	270	368	405	414	408	381	299	224
TOTAL POPULATION	14551	14732	14920	14920	14920	15065	15256	15306	15505	16011	16870	17477	17704	17758	17918	17793	17356	17064

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1989				1990				1991				1992				1993			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
6408	6408	6408	6408	6490	6490	6490	6490	6573	6573	6573	6573	6657	6657	6657	6657	6742	6742	6742	6742
15699	15699	15699	15699	15900	15900	15900	15900	16104	16104	16104	16104	16310	16310	16310	16310	16518	16518	16510	16518
50	10	0	0	0	0	0	0	0	0	0	20	140	260	300	160	30	0	0	0
550	610	630	630	710	710	710	710	710	710	710	710	730	730	750	830	850	870	870	900
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
454	486	497	497	553	553	553	553	553	553	553	558	602	632	656	677	659	665	665	686
1134	1186	1207	1207	1343	1343	1343	1343	1343	1343	1343	1368	1552	1702	1786	1747	1619	1615	1615	1666
7541	7593	7615	7615	7833	7833	7833	7833	7916	7916	7916	7941	8209	8359	8443	8404	8361	8357	8357	8408
5	1	0	0	0	0	0	0	0	0	0	2	14	26	30	16	3	0	0	0
43	9	0	0	0	0	0	0	0	0	0	17	119	221	255	136	26	0	0	0
3	1	0	0	0	0	0	0	0	0	0	1	7	13	15	8	2	0	0	0
165	183	189	189	213	213	213	213	213	213	213	213	219	219	225	249	255	261	261	270
303	336	347	347	391	391	391	391	391	391	391	391	402	402	413	457	468	479	479	495
83	92	95	95	107	107	107	107	107	107	107	107	110	110	113	125	128	131	131	135
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
136	146	149	149	166	166	166	166	166	166	166	167	181	190	197	203	198	200	200	206
227	243	249	249	277	277	277	277	277	277	277	279	301	316	328	339	329	333	333	343
91	97	99	99	111	111	111	111	111	111	111	112	120	126	131	135	132	133	133	137
54	58	60	60	66	66	66	66	66	66	66	67	72	76	79	81	79	80	80	82
100	107	110	110	122	122	122	122	122	122	122	123	132	139	144	149	145	147	147	151
27	29	30	30	33	33	33	33	33	33	33	34	36	38	39	41	40	40	40	41
385	412	422	422	469	469	469	469	469	469	469	473	510	534	554	573	559	564	564	582
716	738	749	749	833	833	833	833	833	833	833	853	998	1121	1183	1124	1011	1002	1002	1033
215	230	236	236	262	262	262	262	262	262	262	265	285	299	310	320	312	315	315	325
1315	1380	1406	1406	1565	1565	1565	1565	1565	1565	1565	1592	1793	1954	2048	2018	1882	1881	1881	1941
52	10	0	0	0	0	0	0	0	0	0	21	146	272	314	167	31	0	0	0
824	914	944	944	1064	1064	1064	1064	1064	1064	1064	1064	1094	1094	1124	1244	1274	1304	1304	1349
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
571	611	626	626	696	696	696	696	696	696	696	703	758	796	826	852	829	837	837	864
251	269	276	276	307	307	307	307	307	307	307	310	333	349	362	375	365	369	369	381
1819	1925	1966	1966	2187	2187	2187	2187	2187	2187	2187	2217	2452	2631	2746	2758	2620	2634	2634	2713
17518	17624	17665	17665	18087	18087	18087	18087	18291	18291	18291	18321	18761	18941	19056	19068	19138	19149	19149	19232
285	299	304	304	338	338	338	338	338	338	338	344	391	429	450	440	408	407	407	419
17803	17923	17969	17969	18425	18425	18425	18425	18629	18629	18629	18665	19152	19369	19505	19508	19546	19555	19555	19651

1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008-2044
6829	6916	7004	7094	7185	7277	7370	7464	7560	7657	7657	7657	7657	7657	7657
16730	16944	17161	17381	17603	17828	18057	18288	18522	18759	18759	18759	18759	18759	18759
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	910	900	900	910	910	910	910	920	920	920	930	930	930	940
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
686	693	686	686	693	693	693	693	700	700	700	707	707	707	714
1666	1683	1666	1666	1683	1683	1683	1683	1700	1700	1700	1717	1717	1717	1734
8495	8599	8670	8760	8868	8960	9053	9147	9260	9357	9357	9374	9374	9374	9391
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
270	273	270	270	273	273	273	273	276	276	276	279	279	279	282
495	501	495	495	501	501	501	501	506	506	506	512	512	512	517
135	137	135	135	137	137	137	137	138	138	138	140	140	140	141
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
206	208	206	206	208	208	208	208	210	210	210	212	212	212	214
343	347	343	343	347	347	347	347	350	350	350	354	354	354	357
137	139	137	137	139	139	139	139	140	140	140	141	141	141	143
82	83	82	82	83	83	83	83	84	84	84	85	85	85	86
151	153	151	151	153	153	153	153	154	154	154	156	156	156	157
41	42	41	41	42	42	42	42	42	42	42	42	42	42	43
582	588	582	582	588	588	588	588	594	594	594	600	600	600	606
1033	1044	1033	1033	1044	1044	1044	1044	1054	1054	1054	1065	1065	1065	1075
325	329	325	325	329	329	329	329	332	332	332	335	335	335	339
1941	1961	1941	1941	1961	1961	1961	1961	1981	1981	1981	2000	2000	2000	2020
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1349	1364	1349	1349	1364	1364	1364	1364	1379	1379	1379	1394	1394	1394	1409
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
864	872	864	864	872	872	872	872	881	881	881	890	890	890	899
381	385	381	381	385	385	385	385	388	388	388	392	392	392	396
2713	2741	2713	2713	2741	2741	2741	2741	2769	2769	2769	2796	2796	2796	2824
19443	19685	19874	20094	20344	20569	20797	21029	21290	21527	21527	21555	21555	21555	21583
419	424	419	419	424	424	424	424	428	428	428	432	432	432	437
19863	20109	20294	20513	20768	20993	21221	21453	21718	21955	21955	21987	21987	21987	22019

MULTIPLIERS AND FACTORS USED IN THESE CALCULATIONS			
AVGHHSZ=	2.80	VACFM=	3.30
BASESFD=	.70	PHS1SFD=	.60
BASEMFD=	.23	PHS1MFD=	.30
BASEMBL=	.07	PHS1MBL=	.10
BASESAC=	.46	PHS2SFD=	.65
CONFM=	2.30	PHS2MFD=	.25
OPRFM=	3.30	PHS2MBL=	.10
KOFM=	3.30	INMSAC=	.94
SECFM=	3.30		

TABLE I-1B

KETCHIKAN-GATEWAY BOROUGH
HOUSING AND SCHOOL ENROLLMENT FORECAST
COMMUTE OPTION

ITEM DESCRIPTION : YEAR	1983	1984	1985				1986				1987				1988			
: QTR			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
BASELINE																		
BASELINE NON-AG EMP	5937	6013	6090	6090	6090	6090	6168	6168	6168	6168	6247	6247	6247	6247	6327	6327	6327	6327
BASELINE POPULATION	14551	14732	14920	14920	14920	14920	15111	15111	15111	15111	15305	15305	15305	15305	15501	15501	15501	15501
BASELINE HOUSING TYPE																		
SINGLE FAMILY DWELLING	3612	3657	3704	3704	3704	3704	3751	3751	3751	3751	3799	3799	3799	3799	3848	3848	3848	3848
MULTI-FAMILY DWELLING	1187	1202	1217	1217	1217	1217	1232	1232	1232	1232	1248	1248	1248	1248	1264	1264	1264	1264
MOBILE DWELLING	361	366	370	370	370	370	375	375	375	375	380	380	380	380	385	385	385	385
TOTAL HOUSING UNITS	5160	5224	5291	5291	5291	5291	5359	5359	5359	5359	5427	5427	5427	5427	5497	5497	5497	5497
BSLINE SCHOOLAGE CHILDRN (AVG DAILY MEMBRSHIP)	2394	2403	2434	2434	2434	2434	2465	2465	2465	2465	2497	2497	2497	2497	2528	2528	2528	2528
RESIDENCE OF PROJ IND POP																		
CONSTRUCTION POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	72	72	81	180	432	747	954	1035	1062	1044	918	621	126
KETCHIKAN/OTHER KGB	0	0	0	0	0	12	12	13	29	70	121	154	167	172	169	148	100	20
OPERATIONS POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	0	0	0	0	0	15	105	135	135	135	195	270	570
KETCHIKAN OFFICE POP																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	45
SECONDARY POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	25	25	37	72	160	279	404	450	460	453	444	385	405
VACATED LOCAL JOBS POP																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	11	11	16	31	68	118	172	192	196	193	190	166	178
TOTAL QUARTZ HILL POP	0	0	0	0	0	72	72	81	180	432	747	954	1035	1062	1044	918	621	126
TOTAL PROJ IND KGB POP	0	0	0	0	0	47	47	81	146	313	548	851	959	977	965	993	936	1218
TOTAL KGB POP (EXCL QH)	14551	14732	14920	14920	14920	14968	15159	15192	15258	15424	15853	16155	16264	16282	16466	16494	16436	16719
HOUSING TYPE IN KETCHIKAN/OTHER KGB																		
TOTAL PROJ IND HOUSING	0	0	0	0	0	17	17	29	52	111	194	302	340	347	342	352	332	432
SINGLE FAMILY DWELLING																		
PROJECT INDUCED	0	0	0	0	0	10	10	17	31	67	117	181	204	208	205	211	199	259
TOTAL	3612	3657	3704	3704	3704	3714	3761	3768	3782	3818	3916	3980	4003	4007	4053	4059	4047	4107
MULTI-FAMILY DWELLING																		
PROJECT INDUCED	0	0	0	0	0	5	5	9	16	33	58	90	102	104	103	106	100	130
TOTAL	1187	1202	1217	1217	1217	1222	1238	1241	1248	1266	1307	1339	1350	1352	1367	1370	1364	1394
MOBILE DWELLING																		
PROJECT INDUCED	0	0	0	0	0	2	2	3	5	11	19	30	34	35	34	35	33	43
TOTAL	361	366	370	370	370	372	377	378	380	386	399	410	414	415	419	420	418	428
TOTAL HOUSING UNITS	5160	5224	5291	5291	5291	5308	5375	5387	5411	5469	5622	5729	5767	5774	5839	5849	5828	5929
SCHOOLAGE CHLDRN IN KETCHIKAN/OTHER KGB (AVERAGE DAILY MEMBERSHIP)																		
FROM CONST. FAMILIES	0	0	0	0	0	5	5	5	12	29	49	63	68	70	69	61	41	8
FROM OPERATIONS FAMILIES	0	0	0	0	0	0	0	0	0	0	4	30	38	38	38	55	77	162
FROM KETCHKN OFFICE FAM	0	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	4	13
FROM SECONDARY FAMILIES	0	0	0	0	0	7	7	11	20	46	79	115	128	131	129	127	110	115
FROM VAC LOCAL JOB FAM	0	0	0	0	0	3	3	5	9	19	34	49	55	56	55	54	47	51
TOTAL PROJ IND CHILDREN	0	0	0	0	0	15	15	25	45	98	171	261	294	300	296	301	279	350
TOTAL SCHOOLAGE CHILDREN	2394	2403	2434	2434	2434	2449	2480	2490	2510	2563	2668	2758	2791	2796	2824	2830	2807	2878

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1989 1	2	3	4	1990 1	2	3	4	1991 1	2	3	4	1992 1	2	3	4	1993 1	2	3	4
6408	6408	6408	6408	6490	6490	6490	6490	6573	6573	6573	6573	6657	6657	6657	6657	6742	6742	6742	6742
15699	15699	15699	15699	15900	15900	15900	15900	16104	16104	16104	16104	16310	16310	16310	16310	16518	16518	16518	16518
3897	3897	3897	3897	3947	3947	3947	3947	3997	3997	3997	3997	4049.	4049	4049	4049	4100	4100	4100	4100
1280	1280	1280	1280	1297	1297	1297	1297	1313	1313	1313	1313	1330	1330	1330	1330	1347	1347	1347	1347
390	390	390	390	395	395	395	395	400	400	400	400	405	405	405	405	410	410	410	410
5567	5567	5567	5567	5638	5638	5638	5638	5710	5710	5710	5710	5784	5784	5784	5784	5858	5858	5858	5858
2561	2561	2561	2561	2594	2594	2594	2594	2627	2627	2627	2627	2660	2660	2660	2660	2695	2695	2695	2695

45	9	0	0	0	0	0	0	0	0	0	18	126	234	270	144	27	0	0	0
7	1	0	0	0	0	0	0	0	0	0	3	20	38	44	23	4	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
824	914	944	944	1064	1064	1064	1064	1064	1064	1064	1064	1094	1094	1124	1244	1274	1304	1304	1349
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
571	611	626	626	696	696	696	696	696	696	696	703	758	796	826	852	829	837	837	864
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
251	269	276	276	307	307	307	307	307	307	307	310	333	349	362	375	365	369	369	381
45	9	0	0	0	0	0	0	0	0	0	18	126	234	270	144	27	0	0	0
1774	1916	1966	1966	2187	2187	2187	2187	2187	2187	2187	2199	2326	2397	2476	2614	2593	2630	2630	2713
17473	17615	17665	17665	18087	18087	18087	18087	18291	18291	18291	18303	18635	18707	18786	18924	19111	19149	19149	19232

629	680	697	697	776	776	776	776	776	776	776	780	825	850	878	927	919	933	933	962
377	408	418	418	504	504	504	504	504	504	504	507	536	552	571	603	598	606	606	625
4274	4305	4315	4315	4451	4451	4451	4451	4501	4501	4501	4504	4585	4601	4619	4651	4698	4707	4707	4726
189	204	209	209	194	194	194	194	194	194	194	195	206	212	219	232	230	233	233	241
1469	1484	1490	1490	1491	1491	1491	1491	1507	1507	1507	1508	1536	1543	1550	1562	1577	1580	1580	1588
63	68	70	70	78	78	78	78	78	78	78	78	82	85	88	93	92	93	93	96
453	458	459	459	472	472	472	472	477	477	477	478	487	490	493	498	502	503	503	506
6196	6247	6264	6264	6414	6414	6414	6414	6486	6486	6486	6490	6608	6634	6662	6711	6777	6790	6790	6820

3	1	0	0	0	0	0	0	0	0	0	1	8	15	18	10	2	0	0	0
235	260	269	269	303	303	303	303	303	303	303	303	312	312	320	354	363	371	371	384
34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
163	174	178	178	198	198	198	198	198	198	198	200	216	227	235	243	236	238	238	246
72	77	79	79	87	87	87	87	87	87	87	88	95	100	103	107	104	105	105	106
506	546	560	560	623	623	623	623	623	623	623	627	665	687	711	748	739	749	749	773
3067	3107	3121	3121	3217	3217	3217	3217	3250	3250	3250	3254	3325	3348	3371	3408	3434	3444	3444	3467

1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008-2044
6829	6916	7004	7094	7185	7277	7370	7464	7560	7657	7657	7657	7657	7657	7657
16730	16944	17161	17381	17603	17828	18057	18288	18522	18759	18759	18759	18759	18759	18759
4153	4206	4260	4314	4370	4425	4482	4540	4598	4656	4656	4656	4656	4656	4656
1364	1382	1400	1418	1436	1454	1473	1492	1511	1530	1530	1530	1530	1530	1530
415	421	426	431	437	443	448	454	460	466	466	466	466	466	466
5933	6009	6085	6163	6242	6322	6403	6485	6568	6652	6652	6652	6652	6652	6652
2729	2764	2799	2835	2871	2908	2945	2983	3021	3060	3060	3060	3060	3060	3060
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1349	1364	1349	1349	1364	1364	1364	1364	1379	1379	1379	1394	1394	1394	1409
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
864	872	864	864	872	872	872	872	881	881	881	890	890	890	899
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
381	385	381	381	385	385	385	385	388	388	388	392	392	392	396
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2713	2741	2713	2713	2741	2741	2741	2741	2769	2769	2769	2796	2796	2796	2824
19443	19685	19874	20094	20344	20569	20797	21029	21290	21527	21527	21555	21555	21555	21583
962	972	962	962	972	972	972	972	982	982	982	992	992	992	1001
625	632	625	625	632	632	632	632	638	638	638	645	645	645	651
4778	4838	4885	4940	5001	5057	5114	5171	5236	5295	5295	5301	5301	5301	5307
241	243	241	241	243	243	243	243	245	245	245	248	248	248	250
1605	1625	1640	1658	1679	1697	1716	1735	1756	1775	1775	1778	1778	1778	1780
96	97	96	96	97	97	97	97	98	98	98	99	99	99	100
311	318	322	328	334	340	345	351	358	364	364	365	365	365	366
6895	6980	7048	7125	7214	7294	7375	7457	7550	7634	7634	7644	7644	7644	7653
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
384	388	384	384	388	388	388	388	393	393	393	397	397	397	401
34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
246	249	246	246	249	249	249	249	251	251	251	254	254	254	256
108	110	108	108	110	110	110	110	111	111	111	112	112	112	113
773	781	773	773	781	781	781	781	789	789	789	796	796	796	804
3502	3545	3572	3608	3652	3689	3726	3764	3810	3849	3849	3856	3856	3856	3864

TABLE I-2A

KETCHIKAN-GATEWAY BOROUGH
EMPLOYMENT AND POPULATION FORECAST
TOWNSITE SCENARIO

MULTIPLIERS AND FACTORS USED IN THESE CALCULATIONS

GRBASEMP=	.0120	SPSOPER=	.15	IMMVAC=	.55
POPEMULT=	2.45	LOCKO=	.30	SPSVAC=	.15
SECMULTC=	.25	IMMKO=	.55	POPPCON=	.23
SECMULTD=	.70	SPSKO	.15	POPPOPR=	1.73
LOCCON=	.10	LOCSEC=	.30	POPPKO=	1.73
IMMCON=	.85	IMMSEC=	.50	POPPSEC=	1.52
SPSCON=	.05	SPSSEC=	.20	POPPVAC=	1.52
LOCOPER=	.30	LOCLV=	.35	SPECIMM=	.10
IMMOPER=	.55	LOCVAC=	.30	POPSPEC=	1.52

ITEM DESCRIPTION / YEAR / QTR	1983	1984	1985 1	2	3	4	1986 1	2	3	4	1987 1	2	3	4	1988 1	2	3	4
BASELINE																		
BASELINE NON-AG EMP	5937	6013	6090	6090	6090	6090	6168	6168	6168	6168	6247	6247	6247	6247	6327	6327	6327	6327
BASELINE POPULATION	14551	14732	14920	14920	14920	14920	15111	15111	15111	15111	15305	15305	15305	15305	15501	15501	15501	15501
PROJECT EMPLOYMENT																		
CONSTRUCTION EMPLOYMENT	0	0	0	0	0	80	80	90	200	470	840	1160	1350	1430	1410	1270	890	240
OPERATIONS EMPLOYMENT	0	0	0	0	0	0	0	0	0	0	10	70	90	90	90	130	180	380
KETCHIKAN OFFICE EMPLMNT	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	30
SECONDARY EMPLOYMENT	0	0	0	0	0	20	20	30	57	125	224	346	408	428	423	416	356	347
TOTAL PROJ RLTD EMPLMNT	0	0	0	0	0	100	100	130	267	605	1084	1586	1858	1958	1933	1826	1436	997
TOT NON-AG EMPLOYMENT	5937	6013	6090	6090	6090	6190	6268	6297	6435	6772	7331	7833	8104	8204	8259	8152	7762	7324
SOURCE OF EMPLOYEES																		
CONSTRUCTION																		
LOCAL	0	0	0	0	0	8	8	9	20	47	84	116	135	143	141	127	89	24
IMMIGRANT WORKER	0	0	0	0	0	68	68	77	170	400	714	986	1148	1216	1199	1080	757	204
IMMIGRANT SPOUSE	0	0	0	0	0	4	4	5	10	24	42	58	68	72	71	64	45	12
OPERATIONS																		
LOCAL	0	0	0	0	0	0	0	0	0	0	3	21	27	27	27	39	54	114
IMMIGRANT WORKER	0	0	0	0	0	0	0	0	0	0	6	39	50	50	50	72	99	209
IMMIGRANT SPOUSE	0	0	0	0	0	0	0	0	0	0	2	11	14	14	14	20	27	57
KETCHIKAN OFFICE																		
LOCAL	0	0	0	0	0	0	0	3	3	3	3	3	3	3	3	3	3	9
IMMIGRANT WORKER	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	6	6	17
IMMIGRANT SPOUSE	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	5
SECONDARY JOBS																		
LOCAL	0	0	0	0	0	6	6	9	17	37	67	104	122	128	127	125	107	104
IMMIGRANT WORKER	0	0	0	0	0	10	10	15	29	62	112	173	204	214	211	206	178	174
IMMIGRANT SPOUSE	0	0	0	0	0	4	4	6	11	25	45	69	82	86	85	85	71	69
VACATED LOCAL JOBS																		
LOCAL	0	0	0	0	0	2	2	3	7	14	26	40	47	50	49	46	42	41
IMMIGRANT WORKER	0	0	0	0	0	4	4	6	12	26	48	74	87	91	90	89	76	76
IMMIGRANT SPOUSE	0	0	0	0	0	1	1	2	3	7	13	20	24	25	25	24	21	21
TOTAL JOBS FILLED																		
LOCAL	0	0	0	0	0	16	16	24	47	102	183	284	335	351	347	342	294	293
IMMIGRANT WORKER	0	0	0	0	0	82	82	103	216	494	885	1277	1493	1575	1555	1453	1115	679
IMMIGRANT SPOUSE	0	0	0	0	0	9	9	14	26	57	103	159	188	197	195	192	165	164
TOTAL	0	0	0	0	0	108	108	141	289	653	1170	1720	2015	2123	2096	1987	1574	1135
PROJECT INDUCED POPULATION																		
TOTAL CONSTR POPULATION	0	0	0	0	0	84	84	94	209	491	878	1213	1411	1495	1474	1326	930	251
OPERATIONS POPULATION	0	0	0	0	0	0	0	0	0	0	15	105	135	135	135	195	270	570
KETCHIKAN OFFICE POP	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	45
SECONDARY POPULATION	0	0	0	0	0	25	25	37	72	157	282	436	513	538	532	523	448	437
VACATED JOB POPULATION	0	0	0	0	0	11	11	16	31	67	120	186	219	229	227	224	192	191
TOTAL PROJ INDUCED POP	0	0	0	0	0	119	119	162	326	730	1310	1954	2293	2413	2383	2284	1855	1494
TOTAL POP W/OUT SPEC	14551	14732	14920	14920	14920	15040	15231	15273	15438	15841	16615	17259	17598	17717	17883	17785	17356	16994
SPECULATIVE IMMIGRANTS	0	0	0	0	0	25	25	33	67	152	273	399	468	493	487	460	361	251
TOTAL POPULATION	14551	14732	14920	14920	14920	15065	15256	15306	15505	15993	16888	17658	18066	18210	18370	18245	17717	17245

1989				1990				1991				1992				1993			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
6408	6408	6408	6408	6490	6490	6490	6490	6573	6573	6573	6573	6657	6657	6657	6657	6742	6742	6742	6742
15699	15699	15699	15699	15900	15900	15900	15900	16104	16104	16104	16104	16310	16310	16310	16310	16518	16518	16518	16518
50	10	0	0	0	0	0	0	0	0	0	20	140	260	300	160	30	0	0	0
550	610	630	630	710	710	710	710	710	710	710	710	730	730	750	830	850	870	870	900
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
454	486	497	497	553	553	553	553	553	553	553	558	602	632	656	677	659	665	665	686
1134	1186	1207	1207	1343	1343	1343	1343	1343	1343	1343	1368	1552	1702	1786	1747	1619	1615	1615	1666
7541	7593	7615	7615	7833	7833	7833	7833	7916	7916	7916	7941	8209	8359	8443	8404	8361	8357	8357	8408
5	1	0	0	0	0	0	0	0	0	0	2	14	26	30	16	3	0	0	0
43	9	0	0	0	0	0	0	0	0	0	17	119	221	255	136	26	0	0	0
3	1	0	0	0	0	0	0	0	0	0	1	7	13	15	8	2	0	0	0
165	183	189	189	213	213	213	213	213	213	213	213	219	219	225	249	255	261	261	270
303	336	347	347	391	391	391	391	391	391	391	391	402	402	413	457	468	479	479	495
83	92	95	95	107	107	107	107	107	107	107	107	110	110	113	125	128	131	131	135
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
136	146	149	149	166	166	166	166	166	166	166	167	181	190	197	203	198	206	200	206
227	243	249	249	277	277	277	277	277	277	277	279	301	316	328	339	329	333	333	343
91	97	99	99	111	111	111	111	111	111	111	112	120	126	131	135	132	133	133	137
54	58	60	60	66	66	66	66	66	66	66	67	72	76	79	81	79	86	80	82
100	107	110	110	122	122	122	122	122	122	122	123	132	139	144	149	145	147	147	151
27	29	30	30	33	33	33	33	33	33	33	34	36	38	39	41	40	40	40	41
385	412	422	422	469	469	469	469	469	469	469	473	510	534	554	573	559	566	566	582
716	738	749	749	833	833	833	833	833	833	833	853	998	1121	1183	1124	1011	1002	1002	1033
215	230	236	236	262	262	262	262	262	262	262	265	285	299	310	320	312	315	315	325
1315	1380	1406	1406	1565	1565	1565	1565	1565	1565	1565	1592	1793	1954	2048	2018	1882	1881	1881	1941
52	10	0	0	0	0	0	0	0	0	0	21	146	272	314	167	31	0	0	0
824	914	944	944	1064	1064	1064	1064	1064	1064	1064	1064	1094	1094	1124	1244	1274	1304	1304	1349
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
571	611	626	626	696	696	696	696	696	696	696	703	758	796	826	852	829	837	837	864
251	269	276	276	307	307	307	307	307	307	307	310	333	349	362	375	365	369	369	381
1819	1925	1966	1966	2187	2187	2187	2187	2187	2187	2187	2217	2452	2631	2746	2758	2620	2630	2630	2713
17518	17624	17665	17665	18087	18087	18087	18087	18291	18291	18291	18321	18761	18941	19056	19068	19138	19149	19149	19232
285	299	304	304	338	338	338	338	338	338	338	344	391	429	450	440	408	407	407	419
17803	17923	17969	17969	18425	18425	18425	18425	18629	18629	18629	18665	19152	19369	19505	19508	19546	19556	19555	19651

Townsite
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1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008-2044
6829	6916	7004	7094	7185	7277	7370	7464	7560	7657	7657	7657	7657	7657	7657
16730	16944	17161	17381	17603	17828	18057	18288	18522	18759	18759	18759	18759	18759	18759
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	910	900	900	910	910	910	910	920	920	920	930	930	930	940
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
686	693	686	686	693	693	693	693	700	700	700	707	707	707	714
1666	1683	1666	1666	1683	1683	1683	1683	1700	1700	1700	1717	1717	1717	1734
8495	8599	8670	8760	8868	8960	9053	9147	9260	9357	9357	9374	9374	9374	9391
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
270	273	270	270	273	273	273	273	276	276	276	279	279	279	282
495	501	495	495	501	501	501	501	506	506	506	512	512	512	517
135	137	135	135	137	137	137	137	138	138	138	140	140	140	141
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
206	208	206	206	208	208	208	208	210	210	210	212	212	212	214
343	347	343	343	347	347	347	347	350	350	350	354	354	354	357
137	139	137	137	139	139	139	139	140	140	140	141	141	141	143
82	83	82	82	83	83	83	83	84	84	84	85	85	85	86
151	153	151	151	153	153	153	153	154	154	154	156	156	156	157
41	42	41	41	42	42	42	42	42	42	42	42	42	42	43
582	588	582	582	588	588	588	588	594	594	594	600	600	600	606
1033	1044	1033	1033	1044	1044	1044	1044	1054	1054	1054	1065	1065	1065	1075
325	329	325	325	329	329	329	329	332	332	332	335	335	335	339
1941	1961	1941	1941	1961	1961	1961	1961	1981	1981	1981	2000	2000	2000	2020
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1349	1364	1349	1349	1364	1364	1364	1364	1379	1379	1379	1394	1394	1394	1409
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
864	872	864	864	872	872	872	872	881	881	881	890	890	890	899
381	385	381	381	385	385	385	385	388	388	388	392	392	392	396
2713	2741	2713	2713	2741	2741	2741	2741	2769	2769	2769	2796	2796	2796	2824
19443	19685	19874	20094	20344	20569	20797	21029	21290	21527	21527	21555	21555	21555	21583
419	424	419	419	424	424	424	424	428	428	428	432	432	432	437
19863	20109	20294	20513	20768	20993	21221	21452	21718	21955	21955	21987	21987	21987	22019

MULTIPLIERS AND FACTORS USED IN THESE CALCULATIONS

AVGHHSZ=	2.82	VACFM=	3.30
BASESFD=	.70	PHS1SFD=	.60
BASEMFD=	.23	PHS1MFD=	.30
BASEMBL=	.07	PHS1MBL=	.10
BASESAC=	.46	PHS2SFD=	.65
CONFM=	2.30	PHS2MFD=	.25
OPRFM=	3.30	PHS2MBL=	.10
KOFM=	3.30	INMSAC=	.94
SCEFM=	3.30		

TABLE I-2B

KETCHIKAN-GATEWAY BOROUGH
HOUSING AND SCHOOL ENROLLMENT FORECAST
TOWNSITE OPTION

ITEM DESCRIPTION / YEAR	1983	1984	1985				1986				1987				1988			
QTR			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
BASELINE																		
BASELINE NON-AG EMP	5937	6013	6090	6090	6090	6090	6168	6168	6168	6168	6247	6247	6247	6247	6327	6327	6327	6327
BASELINE POPULATION	14551	14732	14920	14920	14920	14920	15111	15111	15111	15111	15305	15305	15305	15305	15501	15501	15501	15501
BASELINE HOUSING TYPE																		
SINGLE FAMILY DWELLING	3612	3657	3704	3704	3704	3704	3751	3751	3751	3751	3799	3799	3799	3799	3848	3848	3848	3848
MULTI-FAMILY DWELLING	1187	1202	1217	1217	1217	1217	1232	1232	1232	1232	1248	1248	1248	1248	1264	1264	1264	1264
MOBILE DWELLING	361	366	370	370	370	370	375	375	375	375	380	380	380	380	385	385	385	385
TOTAL HOUSING UNITS	5160	5224	5291	5291	5291	5291	5359	5359	5359	5359	5427	5427	5427	5427	5497	5497	5497	5497
BSLINE SCHOOLAGE CHILDRN (AVG DAILY MEMBRSHIP)	2394	2403	2434	2434	2434	2434	2465	2465	2465	2465	2497	2497	2497	2497	2528	2528	2528	2528
RESIDENCE OF PROJ IND POP																		
CONSTRUCTION POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	72	72	81	180	423	756	1044	1215	1287	1269	1143	801	216
KETCHIKAN/OTHER KGB	0	0	0	0	0	12	12	13	29	68	122	169	196	208	205	185	129	35
OPERATIONS POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	0	0	0	0	0	15	105	135	135	135	195	270	570
KETCHIKAN OFFICE POP																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	45
SECONDARY POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	25	25	37	72	157	282	436	513	538	532	523	448	437
VACATED LOCAL JOBS POP																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	11	11	16	31	67	120	186	219	229	227	224	192	191
TOTAL QUARTZ HILL POP	0	0	0	0	0	72	72	81	180	423	756	1044	1215	1287	1269	1143	801	216
TOTAL PROJ IND KGB POP	0	0	0	0	0	47	47	81	146	307	554	910	1078	1126	1114	1141	1054	1278
TOTAL KGB POP (EXCL QH)	14551	14732	14920	14920	14920	14968	15159	15192	15258	15418	15859	16215	16383	16430	16614	16642	16555	16778
HOUSING TYPE IN KETCHIKAN/OTHER KGB																		
TOTAL PROJ IND HOUSING	0	0	0	0	0	17	17	29	52	109	196	323	382	399	395	405	374	453
SINGLE FAMILY DWELLING																		
PROJECT INDUCED	0	0	0	0	0	10	10	17	31	65	118	194	229	239	237	243	224	272
TOTAL	3612	3657	3704	3704	3704	3714	3761	3768	3782	3816	3917	3993	4028	4039	4085	4091	4072	4120
MULTI-FAMILY DWELLING																		
PROJECT INDUCED	0	0	0	0	0	5	5	9	16	33	59	97	115	120	118	121	112	136
TOTAL	1187	1202	1217	1217	1217	1222	1238	1241	1248	1265	1307	1345	1363	1368	1383	1386	1376	1400
MOBILE DWELLING																		
PROJECT INDUCED	0	0	0	0	0	2	2	3	5	11	20	32	38	40	39	40	37	45
TOTAL	361	366	370	370	370	372	377	378	380	386	400	412	418	420	424	425	422	430
TOTAL HOUSING UNITS	5160	5224	5291	5291	5291	5308	5375	5387	5411	5467	5624	5750	5810	5826	5892	5901	5871	5950
SCHOOLAGE CHLDRN IN KETCHIKAN/OTHER KGB (AVERAGE DAILY MEMBERSHIP)																		
FROM CONST. FAMILIES	0	0	0	0	0	5	5	5	12	28	50	69	80	85	84	76	53	14
FROM OPERATIONS FAMILIES	0	0	0	0	0	0	0	0	0	0	4	30	38	38	38	55	77	162
FROM KETCHKN OFFICE FAM	0	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	4	13
FROM SECONDARY FAMILIES	0	0	0	0	0	7	7	11	20	45	80	124	146	153	152	149	127	124
FROM VAC LOCAL JOB FAM	0	0	0	0	0	3	3	5	9	19	34	53	62	65	65	64	55	54
TOTAL PROJ IND CHILDREN	0	0	0	0	0	15	15	25	45	96	173	280	331	346	343	348	316	368
TOTAL SCHOOLAGE CHILDREN	2394	2403	2434	2434	2434	2449	2480	2490	2510	2561	2669	2777	2828	2843	2871	2876	2845	2897

1989				1990				1991				1992				1993			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
6408	6408	6408	6408	6490	6490	6490	6490	6573	6573	6573	6573	6657	6657	6657	6657	6742	6742	6742	6742
15699	15699	15699	15699	15900	15900	15900	15900	16104	16104	16104	16104	16310	16310	16310	16310	16518	16518	16518	16518
3897	3897	3897	3897	3947	3947	3947	3947	3997	3997	3997	3997	4049	4049	4049	4049	4100	4100	4100	4100
1280	1280	1280	1280	1297	1297	1297	1297	1313	1313	1313	1313	1330	1330	1330	1330	1347	1347	1347	1347
390	390	390	390	395	395	395	395	400	400	400	400	405	405	405	405	410	410	410	410
5567	5567	5567	5567	5638	5638	5638	5638	5710	5710	5710	5710	5784	5784	5784	5784	5858	5858	5858	5858
2561	2561	2561	2561	2594	2594	2594	2594	2627	2627	2627	2627	2660	2660	2660	2660	2695	2695	2695	2695
45	9	0	0	0	0	0	0	0	0	0	18	126	234	270	144	27	0	0	0
7	1	0	0	0	0	0	0	0	0	0	3	20	38	44	23	4	0	0	0
824	914	944	944	1064	1064	1064	1064	1064	1064	1064	1064	1094	1094	1124	1244	1274	1304	1304	1349
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
252	252	252	252	302	302	302	302	378	378	378	378	453	453	453	453	529	529	529	529
319	359	374	374	394	394	394	394	319	319	319	325	305	342	373	399	300	308	308	335
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
251	269	276	276	307	307	307	307	307	307	307	310	333	349	362	375	365	369	369	381
1121	1175	1196	1196	1366	1366	1366	1366	1442	1442	1442	1460	1673	1781	1847	1841	1830	1833	1833	1878
698	750	770	770	821	821	821	821	745	745	745	757	778	849	899	917	790	797	797	835
16397	16449	16469	16469	16721	16721	16721	16721	16849	16849	16849	16861	17088	17159	17208	17227	17308	17316	17316	17354
247	266	273	273	291	291	291	291	264	264	264	269	276	301	319	325	280	283	283	296
148	160	164	164	189	189	189	189	172	172	172	175	179	196	207	211	182	184	184	193
4045	4057	4061	4061	4136	4136	4136	4136	4169	4169	4169	4172	4228	4244	4256	4260	4282	4284	4284	4293
74	80	82	82	73	73	73	73	66	66	66	67	69	75	80	81	70	71	71	74
1355	1360	1362	1362	1370	1370	1370	1370	1379	1379	1379	1381	1399	1406	1410	1412	1417	1418	1418	1421
25	27	27	27	29	29	29	29	26	26	26	27	28	30	32	33	28	28	28	30
414	416	417	417	424	424	424	424	426	426	426	427	432	435	437	437	438	438	438	440
5814	5833	5840	5840	5929	5929	5929	5929	5975	5975	5975	5979	6060	6085	6102	6109	6138	6140	6140	6154
3	1	0	0	0	0	0	0	0	0	0	1	8	15	18	10	2	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
91	102	107	107	112	112	112	112	91	91	91	93	87	98	106	114	86	88	88	95
72	77	79	79	87	87	87	87	87	87	87	88	95	100	103	107	104	105	105	108
200	214	219	219	234	234	234	234	212	212	212	216	224	247	261	264	226	227	227	238
2760	2775	2780	2780	2827	2827	2827	2827	2839	2839	2839	2843	2685	2907	2922	2925	2920	2922	2922	2932

1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008-2044
6829	6916	7004	7094	7185	7277	7370	7464	7560	7657	7657	7657	7657	7657	7657
16730	16944	17161	17381	17603	17828	18057	18288	18522	18759	18759	18759	18759	18759	18759
4153	4206	4260	4314	4370	4425	4482	4540	4598	4656	4656	4656	4656	4656	4656
1364	1382	1400	1418	1436	1454	1473	1492	1511	1530	1530	1530	1530	1530	1530
415	421	426	431	437	443	448	454	460	466	466	466	466	466	466
5933	6009	6085	6163	6242	6322	6403	6485	6568	6652	6652	6652	6652	6652	6652
2729	2764	2799	2835	2871	2908	2945	2983	3021	3060	3060	3060	3060	3060	3060
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1349	1364	1349	1349	1364	1364	1364	1364	1379	1379	1379	1394	1394	1394	1409
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
604	604	604	604	604	604	604	604	604	604	604	604	604	604	604
259	268	259	259	268	268	268	268	277	277	277	286	286	286	295
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
381	385	381	381	385	385	385	385	388	388	388	392	392	392	396
1953	1968	1953	1953	1968	1968	1968	1968	1983	1983	1983	1998	1998	1998	2013
760	773	760	760	773	773	773	773	785	785	785	798	798	798	811
17490	17717	17921	18141	18376	18601	18829	19060	19307	19544	19544	19557	19557	19557	19570
269	274	269	269	274	274:	274	274	278	278	278	283	283	283	287
175	178	175	175	178	178	178	178	181	181	181	184	184	184	187
4328	4384	4433	4489	4540	4604	4660	4718	4779	4837	4837	4840	4840	4840	4843
67	68	67	67	68	68	68	68	70	70	70	71	71	71	72
1432	1450	1467	1485	1504	1523	1541	1560	1580	1600	1600	1601	1601	1601	1602
27	27	27	27	27	27	27	27	28	28	28	28	28	28	29
442	448	453	[illegible]	464	470	476	481	488	493	493	494	494	494	494
6202	6283	6385	6433	6516	6596	6677	6759	6847	6931	6931	6935	6935	6935	6940
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
74	76	74	74	76	76	76	76	79	79	79	81	81	81	84
108	110	108	108	110	110	110	110	111	111	111	112	112	112	113
216	220	216	216	220	220	220	220	224	224	224	227	227	227	231
2945	2984	3016	3052	3092	3128	3165	3203	3245	3284	3284	3287	3287	3287	3291

TABLE I-3A
KETCHIKAN-GATEWAY BOROUGH
EMPLOYMENT AND POPULATION FORECAST
PHASE-IN SCENARIO

MULTIPLIERS AND FACTORS USED IN THESE CALCULATIONS

GRBASEMP=	.0128	SPSOPER=	.15	IMMVAC=	.55
POPEMULT=	2.45	LOCKO=	.30	SPSVAC=	.15
SECMULTC=	.25	IMMKO=	.55	POPPCON=	.23
SECMULTO=	.70	SPSKO	.15	POPPOPN=	1.73
LOCCON=	.10	LOCSEC=	.30	POPPKO=	1.73
IMMCON=	.85	IMMSEC=	.50	POPPSEC=	1.52
SPSCON=	.05	SPSSEC=	.20	POPPVAC=	1.52
LOCOPER=	.30	LOCLV=	.55	SPECIMM=	.10
IMMOPER=	.55	LOCVAC=	.30	POPSPEC=	1.52

ITEM DESCRIPTION : YEAR	1983	1984	1985				1986				1987				1988			
: QTR			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
BASELINE																		
BASELINE NON-AG EMP	5937	6013	6090	6090	6090	6090	6168	6168	6168	6168	6247	6247	6247	6247	6327	6327	6327	6327
BASELINE POPULATION	14551	14732	14920	14920	14920	14920	15111	15111	15111	15111	15305	15305	15305	15305	15501	15501	15501	15501
PROJECT EMPLOYMENT																		
CONSTRUCTION EMPLOYMENT	0	0	0	0	0	80	80	90	200	480	840	1060	1150	1180	1160	1020	690	140
OPERATIONS EMPLOYMENT	0	0	0	0	0	0	0	0	0	0	10	70	90	90	90	130	180	380
KETCHIKAN OFFICE EMPLMNT	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	30
SECONDARY EMPLOYMENT	0	0	0	0	0	20	20	30	57	127	224	321	358	365	360	353	306	322
TOTAL PROJ RLTD EMPLMNT	0	0	0	0	0	100	100	130	267	617	1084	1461	1608	1645	1620	1513	1186	872
TOT NON-AG EMPLOYMENT	5937	6013	6090	6090	6090	6190	6268	6297	6435	6785	7331	7708	7854	7892	7947	7840	7512	7199
SOURCE OF EMPLOYEES																		
CONSTRUCTION																		
LOCAL	0	0	0	0	0	8	8	9	20	48	84	106	115	118	116	102	69	14
IMMIGRANT WORKER	0	0	0	0	0	68	68	77	170	408	714	901	978	1003	986	867	587	119
IMMIGRANT SPOUSE	0	0	0	0	0	4	4	5	10	24	42	53	58	59	58	51	35	7
OPERATIONS																		
LOCAL	0	0	0	0	0	0	0	0	0	0	3	21	27	27	27	39	54	114
IMMIGRANT WORKER	0	0	0	0	0	0	0	0	0	0	6	39	50	50	50	72	99	209
IMMIGRANT SPOUSE	0	0	0	0	0	0	0	0	0	0	2	11	14	14	14	20	27	57
KETCHIKAN OFFICE																		
LOCAL	0	0	0	0	0	0	0	3	3	3	3	3	3	3	3	3	3	9
IMMIGRANT WORKER	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	6	6	17
IMMIGRANT SPOUSE	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	5
SECONDARY JOBS																		
LOCAL	0	0	0	0	0	6	6	9	17	38	67	96	107	110	108	106	92	97
IMMIGRANT WORKER	0	0	0	0	0	10	10	15	29	64	112	161	179	183	180	177	153	161
IMMIGRANT SPOUSE	0	0	0	0	0	4	4	6	11	25	45	64	72	73	72	71	61	64
VACATED LOCAL JOBS																		
LOCAL	0	0	0	0	0	2	2	3	7	15	26	37	42	42	42	41	36	39
IMMIGRANT WORKER	0	0	0	0	0	4	4	6	12	27	48	68	76	78	77	76	66	71
IMMIGRANT SPOUSE	0	0	0	0	0	1	1	2	3	7	13	19	21	21	21	21	18	19
TOTAL JOBS FILLED																		
LOCAL	0	0	0	0	0	16	16	24	47	104	183	264	294	300	296	291	254	272
IMMIGRANT WORKER	0	0	0	0	0	82	82	103	216	504	885	1174	1288	1318	1298	1196	910	576
IMMIGRANT SPOUSE	0	0	0	0	0	9	9	14	26	58	103	148	165	168	166	163	142	152
TOTAL	0	0	0	0	0	108	108	141	289	666	1170	1585	1746	1787	1760	1650	1305	1000
PROJECT INDUCED POPULATION																		
TOTAL CONSTR POPULATION	0	0	0	0	0	84	84	94	209	502	878	1108	1202	1234	1213	1066	721	146
OPERATIONS POPULATION	0	0	0	0	0	0	0	0	0	0	15	105	135	135	135	195	270	570
KETCHIKAN OFFICE POP	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	45
SECONDARY POPULATION	0	0	0	0	0	25	25	37	72	160	282	404	450	460	453	444	385	405
VACATED JOB POPULATION	0	0	0	0	0	11	11	16	31	68	120	172	192	196	193	190	166	178
TOTAL PROJ INDUCED POP	0	0	0	0	0	119	119	162	326	745	1310	1805	1994	2039	2009	1911	1557	1344
TOTAL POP W/OUT SPEC	14551	14732	14920	14920	14920	15040	15231	15273	15438	15856	16615	17109	17299	17344	17510	17412	17057	16845
SPECULATIVE IMMIGRANTS	0	0	0	0	0	25	25	33	67	155	273	368	405	414	408	381	299	220
TOTAL POPULATION	14551	14732	14920	14920	14920	15065	15256	15306	15505	16011	16888	17477	17704	17758	17918	17793	17356	17064

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1989				1990				1991				1992				1993			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
6408	6408	6408	6408	6490	6490	6490	6490	6573	6573	6573	6573	6657	6657	6657	6657	6742	6742	6742	6742
15699	15699	15699	15699	15900	15900	15900	15900	16104	16104	16104	16104	16310	16310	16310	16310	16518	16518	16518	16518
100	70	70	100	100	100	100	100	100	100	100	120	240	330	360	210	30	0	0	0
550	610	630	630	710	710	710	710	710	710	710	710	730	730	750	830	850	870	870	900
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
466	501	515	522	578	578	578	578	578	578	578	583	627	650	671	690	659	665	665	686
1196	1261	1295	1332	1468	1468	1468	1468	1468	1468	1468	1493	1677	1790	1861	1810	1619	1615	1615	1666
7604	7668	7702	7740	7958	7958	7958	7958	8041	8041	8041	8066	8334	8447	8518	8467	8361	8357	8357	8408
10	7	7	10	10	10	10	10	10	10	10	12	24	33	36	21	3	0	0	0
85	60	60	85	85	85	85	85	85	85	85	102	204	281	306	179	26	0	0	0
5	4	4	5	5	5	5	5	5	5	5	6	12	17	18	11	2	0	0	0
165	183	189	189	213	213	213	213	213	213	213	213	219	219	225	249	255	261	261	270
303	336	347	347	391	391	391	391	391	391	391	391	402	402	413	457	468	479	479	495
83	92	95	95	107	107	107	107	107	107	107	107	110	110	113	125	128	131	131	135
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
140	150	154	157	173	173	173	173	173	173	173	175	188	195	201	207	198	200	200	206
233	250	257	261	289	289	289	289	289	289	289	292	314	325	336	345	329	333	333	343
93	100	103	104	116	116	116	116	116	116	116	117	125	130	134	138	132	133	133	137
56	60	62	63	69	69	69	69	69	69	69	70	75	78	80	83	79	80	80	82
102	110	113	115	127	127	127	127	127	127	127	128	138	142	147	152	145	147	147	151
28	30	31	31	35	35	35	35	35	35	35	35	38	39	40	41	40	40	40	41
395	424	436	442	490	490	490	490	490	490	490	494	530	549	567	583	559	564	564	582
767	799	820	851	936	936	936	936	936	936	936	956	1101	1193	1245	1175	1011	1002	1002	1033
221	237	244	247	274	274	274	274	274	274	274	276	296	307	317	326	312	315	315	325
1382	1461	1500	1541	1699	1699	1699	1699	1699	1699	1699	1726	1927	2048	2128	2085	1882	1881	1881	1941
105	73	73	105	105	105	105	105	105	105	105	125	251	345	376	220	31	0	0	0
824	914	944	944	1064	1064	1064	1064	1064	1064	1064	1064	1094	1094	1124	1244	1274	1304	1304	1349
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
587	630	648	657	728	728	728	728	728	728	728	734	789	818	845	868	829	837	837	864
258	277	285	289	320	320	320	320	320	320	320	323	347	359	370	381	365	369	369	381
1894	2015	2070	2115	2336	2336	2336	2336	2336	2336	2336	2366	2601	2735	2836	2833	2620	2630	2630	2713
17593	17714	17769	17814	18237	18237	18237	18237	18440	18440	18440	18470	18911	19045	19145	19143	19138	19149	19149	19232
301	317	326	335	370	370	370	370	370	370	370	376	422	451	469	456	408	407	407	419
17894	18031	18095	18150	18606	18606	18606	18606	18810	18810	18810	18846	19333	19496	19614	19598	19546	19555	19555	19651

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1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008-2044
6829	6916	7004	7094	7185	7277	7370	7464	7560	7657	7657	7657	7657	7657	7657
16730	16944	17161	17381	17603	17828	18057	18288	18522	18759	18759	18759	18759	18759	18759
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	910	900	900	910	910	910	910	920	920	920	930	930	930	940
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
686	693	686	686	693	693	693	693	700	700	700	707	707	707	714
1666	1683	1666	1666	1683	1683	1683	1683	1700	1700	1700	1717	1717	1717	1734
8495	8599	8670	8760	8868	8960	9053	9147	9260	9357	9357	9374	9374	9374	9391
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
270	273	270	270	273	273	273	273	276	276	276	279	279	279	282
495	501	495	495	501	501	501	501	506	506	506	512	512	512	517
135	137	135	135	137	137	137	137	138	138	138	140	140	140	141
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
206	208	206	206	208	208	208	208	210	210	210	212	212	212	214
343	347	343	343	347	347	347	347	350	350	350	354	354	354	357
137	139	137	137	139	139	139	139	140	140	140	141	141	141	143
82	83	82	82	83	83	83	83	84	84	84	85	85	85	86
151	153	151	151	153	153	153	153	154	154	154	156	156	156	157
41	42	41	41	42	42	42	42	42	42	42	42	42	42	43
582	588	582	582	588	588	588	588	594	594	594	600	600	600	606
1033	1044	1033	1033	1044	1044	1044	1044	1054	1054	1054	1065	1065	1065	1075
325	329	325	325	329	329	329	329	332	332	332	335	335	335	339
1941	1961	1941	1941	1961	1961	1961	1961	1981	1981	1981	2000	2000	2000	2020
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1349	1364	1349	1349	1364	1364	1364	1364	1379	1379	1379	1394	1394	1394	1409
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
864	872	864	864	872	872	872	872	881	881	881	890	890	890	899
381	385	381	381	385	385	385	385	388	388	388	392	392	392	396
2713	2741	2713	2713	2741	2741	2741	2741	2769	2769	2769	2796	2796	2796	2824
19443	19685	19874	20094	20344	20569	20797	21029	21290	21527	21527	21555	21555	21555	21583
419	424	419	419	424	424	424	424	428	428	428	432	432	432	437
19863	20109	20294	20513	20768	20993	21221	21452	21718	21955	21955	21987	21987	21987	22019

TABLE I-3B

KETCHIKAN-GATEWAY BOROUGH
HOUSING AND SCHOOL ENROLLMENT FORECAST
PHASE-IN OPTION

MULTIPLIERS AND FACTORS USED IN THESE CALCULATIONS

AVGHHSZ=	2.82	VACFM=	3.30
BASESFD=	.70	PHS1SFD=	.60
BASEMFD=	.23	PHS1MFD=	.30
BASEMBL=	.07	PHS1MBL=	.10
BASESAC=	.46	PHS2SFD=	.65
CONFM=	2.30	PHS2MFD=	.25
OPRFM=	3.30	PHS2MBL=	.10
KOFM=	3.30	INMSAC=	.94
SCEFM=	3.30		

ITEM DESCRIPTION : YEAR	1983	1984	1985				1986				1987				1988			
: QTR			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
BASELINE																		
BASELINE NON-AG EMP	5937	6013	6090	6090	6090	6090	6168	6168	6168	6168	6247	6247	6247	6247	6327	6327	6327	6327
BASELINE POPULATION	14551	14732	14920	14920	14920	14920	15111	15111	15111	15111	15305	15305	15305	15305	15501	15501	15501	15501
BASELINE HOUSING TYPE																		
SINGLE FAMILY DWELLING	3612	3657	3704	3704	3704	3704	3751	3751	3751	3751	3799	3799	3799	3799	3848	3848	3848	3848
MULTI-FAMILY DWELLING	1187	1202	1217	1217	1217	1217	1232	1232	1232	1232	1248	1248	1248	1248	1264	1264	1264	1264
MOBILE DWELLING	361	366	370	370	370	370	375	375	375	375	380	380	380	380	385	385	385	385
TOTAL HOUSING UNITS	5160	5224	5291	5291	5291	5291	5359	5359	5359	5359	5427	5427	5427	5427	5497	5497	5497	5497
BSLINE SCHOOLAGE CHILDRN (AVG DAILY MEMBRSHIP)	2394	2403	2434	2434	2434	2434	2465	2465	2465	2465	2497	2497	2497	2497	2528	2528	2528	2528
RESIDENCE OF PROJ IND POP																		
CONSTRUCTION POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	72	72	81	180	432	756	954	1035	1062	1044	918	621	126
KETCHIKAN/OTHER KGB	0	0	0	0	0	12	12	13	29	70	122	154	167	172	169	148	100	20
OPERATIONS POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	0	0	0	0	0	15	105	135	135	135	195	270	570
KETCHIKAN OFFICE POP																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	45
SECONDARY POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	25	25	37	72	160	282	404	450	460	453	444	385	405
VACATED LOCAL JOBS POP																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	11	11	16	31	68	120	172	192	196	193	190	166	178
TOTAL QUARTZ HILL POP	0	0	0	0	0	72	72	81	180	432	756	954	1035	1062	1044	918	621	126
TOTAL PROJ IND KGB POP	0	0	0	0	0	47	47	81	146	313	554	851	959	977	965	993	936	1218
TOTAL KGB POP (EXCL QH)	14551	14732	14920	14920	14920	14968	15159	15192	15258	15424	15859	16155	16264	16282	16466	16494	16436	16719
HOUSING TYPE IN KETCHIKAN/OTHER KGB																		
TOTAL PROJ IND HOUSING	0	0	0	0	0	17	17	29	52	111	196	302	340	347	342	352	332	432
SINGLE FAMILY DWELLING																		
PROJECT INDUCED	0	0	0	0	0	10	10	17	31	67	118	181	204	208	205	211	199	259
TOTAL	3612	3657	3704	3704	3704	3714	3761	3768	3782	3818	3917	3980	4003	4007	4053	4059	4047	4107
MULTI-FAMILY DWELLING																		
PROJECT INDUCED	0	0	0	0	0	5	5	9	16	33	59	90	102	104	103	106	100	130
TOTAL	1187	1202	1217	1217	1217	1222	1238	1241	1248	1266	1307	1339	1350	1352	1367	1370	1364	1394
MOBILE DWELLING																		
PROJECT INDUCED	0	0	0	0	0	2	2	3	5	11	20	30	34	35	34	35	33	43
TOTAL	361	366	370	370	370	372	377	378	380	386	400	410	414	415	419	420	418	428
TOTAL HOUSING UNITS	5160	5224	5291	5291	5291	5308	5375	5387	5411	5469	5624	5729	5767	5774	5839	5849	5828	5929
SCHOOLAGE CHLDRN IN KETCHIKAN/OTHER KGB (AVERAGE DAILY MEMBERSHIP)																		
FROM CONST. FAMILIES	0	0	0	0	0	5	5	5	12	29	50	63	68	70	69	61	41	8
FROM OPERATIONS FAMILIES	0	0	0	0	0	0	0	0	0	0	4	30	38	38	38	55	77	162
FROM KETCHKN OFFICE FAM	0	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	4	13
FROM SECONDARY FAMILIES	0	0	0	0	0	7	7	11	20	46	80	115	128	131	129	127	110	115
FROM VAC LOCAL JOB FAM	0	0	0	0	0	3	3	5	9	19	34	49	55	56	55	54	47	51
TOTAL PROJ IND CHILDREN	0	0	0	0	0	15	15	25	45	98	173	261	294	300	296	301	279	350
TOTAL SCHOOLAGE CHILDREN	2394	2403	2434	2434	2434	2449	2480	2490	2510	2563	2669	2758	2791	2796	2824	2830	2807	2878

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1989				1990				1991				1992				1993			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
6408	6408	6408	6408	6490	6490	6490	6490	6573	6573	6573	6573	6657	6657	6657	6657	6742	6742	6742	6742
15699	15699	15699	15699	15900	15900	15900	15900	16104	16104	16104	16104	16310	16310	16310	16310	16518	16518	16518	16518
3897	3897	3897	3897	3947	3947	3947	3947	3997	3997	3997	3997	4049	4049	4049	4049	4100	4100	4100	4100
1280	1280	1280	1280	1297	1297	1297	1297	1313	1313	1313	1313	1330	1330	1330	1330	1347	1347	1347	1347
390	390	390	390	395	395	395	395	400	400	400	400	405	405	405	405	410	410	410	410
5567	5567	5567	5567	5638	5638	5638	5638	5710	5710	5710	5710	5784	5784	5784	5784	5858	5858	5858	5858
2561	2561	2561	2561	2594	2594	2594	2594	2627	2627	2627	2627	2660	2660	2660	2660	2695	2695	2695	2695
90	63	63	90	90	90	90	90	90	90	90	108	216	297	324	189	27	0	0	0
15	10	10	15	15	15	15	15	15	15	15	17	35	48	52	31	4	0	0	0
0	0	0	0	0	0	0	0	0	0	74	149	230	295	371	448	561	678	782	904
824	914	944	944	1064	1064	1064	1064	1064	1064	990	915	864	799	753	796	713	626	522	445
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
252	252	252	252	302	302	302	302	378	378	378	378	453	453	453	453	529	529	529	529
335	370	396	405	426	426	426	426	350	350	350	356	336	364	392	415	300	308	306	335
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
258	277	285	289	320	320	320	320	320	320	320	323	347	359	370	381	365	369	369	381
342	315	315	342	392	392	392	392	468	468	542	635	899	1046	1148	1090	1116	1207	1311	1433
1552	1700	1755	1773	1944	1944	1944	1944	1869	1869	1794	1732	1702	1690	1687	1743	1503	1423	1319	1281
17251	17399	17455	17472	17844	17844	17844	17844	17972	17972	17898	17835	18012	17999	17997	18053	18022	17942	17837	17799
550	603	622	629	689	689	689	689	663	663	636	614	604	599	598	618	533	505	460	454
330	362	373	377	448	448	448	448	431	431	414	399	392	389	389	402	346	320	304	295
4227	4259	4270	4274	4395	4395	4395	4395	4428	4428	4411	4396	4441	4438	4437	4450	4447	4428	4404	4396
165	181	187	189	172	172	172	172	166	166	159	154	151	150	150	155	133	126	117	114
1446	1461	1467	1469	1469	1469	1469	1469	1479	1479	1472	1467	1481	1480	1480	1485	1481	1473	1464	1461
55	60	62	63	69	69	69	69	66	66	64	61	60	60	60	62	53	50	47	45
445	450	452	453	464	464	464	464	466	466	463	461	465	465	465	467	463	461	457	455
6117	6170	6190	6196	6328	6328	6328	6328	6373	6373	6347	6325	6387	6385	6382	6402	6391	6342	6325	6312
6	4	4	6	6	6	6	6	6	6	6	7	14	20	21	12	2	0	0	0
235	260	269	269	303	303	303	303	303	303	282	261	246	228	215	227	203	178	149	127
34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
95	108	113	115	121	121	121	121	100	100	100	101	96	104	112	118	86	88	88	95
74	79	81	82	91	91	91	91	91	91	91	92	99	102	106	109	104	105	105	108
444	486	501	507	556	556	556	556	534	534	513	495	489	487	487	500	429	405	376	365
3005	3046	3062	3068	3149	3149	3149	3149	3161	3161	3140	3122	3150	3148	3148	3161	3123	3100	3070	3059

1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008-2044
6829	6916	7004	7094	7185	7277	7370	7464	7560	7657	7657	7657	7657	7657	7657
16730	16944	17161	17381	17603	17828	18057	18288	18522	18759	18759	18759	18759	18759	18759
4153	4206	4260	4314	4370	4425	4482	4540	4598	4656	4656	4656	4656	4656	4656
1364	1382	1400	1418	1436	1454	1473	1492	1511	1530	1530	1530	1530	1530	1530
415	421	426	431	437	443	448	454	460	466	466	466	466	466	466
5933	6009	6085	6163	6242	6322	6403	6485	6568	6652	6652	6652	6652	6652	6652
2729	2764	2799	2835	2871	2908	2945	2983	3021	3060	3060	3060	3060	3060	3060
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1349	1364	1349	1349	1364	1364	1364	1364	1379	1379	1379	1394	1394	1394	1409
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
604	604	604	604	604	604	604	604	604	604	604	604	604	604	604
259	268	259	259	268	268	268	268	277	277	277	286	286	286	295
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
381	385	381	381	385	385	385	385	388	388	388	392	392	392	396
1953	1968	1953	1953	1968	1968	1968	1968	1983	1983	1983	1998	1998	1998	2013
760	773	760	760	773	773	773	773	785	785	785	798	798	798	811
17490	17717	17921	18141	18376	18601	18829	19060	19307	19544	19544	19557	19557	19557	19570
269	274	269	269	274	274	274	274	278	278	278	283	283	283	287
175	178	175	175	178	178	178	178	181	181	181	184	184	184	187
4328	4384	4435	4489	4548	4604	4660	4718	4779	4837	4837	4840	4840	4840	4843
67	68	67	67	68	68	68	68	70	70	70	71	71	71	72
1432	1450	1467	1485	1504	1523	1541	1560	1580	1600	1600	1601	1601	1601	1602
27	27	27	27	27	27	27	27	28	28	28	28	28	28	29
442	448	453	458	464	470	476	481	488	493	493	494	494	494	494
6202	6283	6358	6433	6516	6596	6677	6759	6847	6931	6931	6935	6935	6935	6940
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
74	76	74	74	76	76	76	76	79	79	79	81	81	81	84
108	110	108	108	110	110	110	110	111	111	111	112	112	112	113
216	220	216	216	220	220	220	220	224	224	224	227	227	227	231
2945	2984	3016	3052	3092	3128	3165	3203	3245	3284	3284	3287	3287	3287	3291

TABLE I-4A

KETCHIKAN-GATEWAY BOROUGH
EMPLOYMENT AND POPULATION FORECAST
TEMPORARY SHUTDOWN SCENARIO

MULTIPLIERS AND FACTORS USED IN THESE CALCULATIONS

GRBASEMP=	.0120	SPSOPER=	.15	IMMVAC=	.55
POPEMULT=	2.45	LOCKO=	.30	SPSVAC=	.15
SECMULTC=	.25	IMMKO=	.55	POPPCON=	.23
SECMULTO=	.70	SPSKO	.15	POPPOPR=	1.73
LOCCON=	.10	LOCSEC=	.30	POPPKO=	1.73
IMMCON=	.85	IMMSEC=	.50	POPPSEC=	1.52
SPSCON=	.05	SPSSEC=	.20	POPPVAC=	1.52
LOCOPER=	.30	LOCLV=	.55	SPECIMM=	.10
IMMOPER=	.55	LOCVAC=	.30	POPSPEC=	1.52

ITEM DESCRIPTION # YEAR	1983	1984	1985				1986				1987				1988			
# QTR			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
BASELINE																		
BASELINE NON-AG EMP	5937	6013	6090	6090	6090	6090	6168	6168	6168	6168	6247	6247	6247	6247	6327	6327	6327	6327
BASELINE POPULATION	14551	14732	14920	14920	14920	14920	15111	15111	15111	15111	15305	15305	15305	15305	15501	15501	15501	15501
PROJECT EMPLOYMENT																		
CONSTRUCTION EMPLOYMENT	0	0	0	0	0	80	80	90	200	480	830	1060	1150	1180	1160	1020	690	140
OPERATIONS EMPLOYMENT	0	0	0	0	0	0	0	0	0	0	10	70	90	90	90	130	180	380
KETCHIKAN OFFICE EMPLMNT	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	30
SECONDARY EMPLOYMENT	0	0	0	0	0	20	20	30	57	127	222	321	358	365	360	353	306	322
TOTAL PROJ RLTD EMPLMNT	0	0	0	0	0	100	100	130	267	617	1072	1461	1608	1645	1620	1513	1186	872
TOT NON-AG EMPLOYMENT	5937	6013	6090	6090	6090	6190	6268	6297	6435	6785	7318	7708	7854	7892	7947	7840	7512	7199
SOURCE OF EMPLOYEES																		
CONSTRUCTION																		
LOCAL	0	0	0	0	0	8	8	9	20	48	83	106	115	118	116	102	69	14
IMMIGRANT WORKER	0	0	0	0	0	68	68	77	170	408	706	901	978	1003	986	867	587	119
IMMIGRANT SPOUSE	0	0	0	0	0	4	4	5	10	24	42	53	58	59	58	51	35	7
OPERATIONS																		
LOCAL	0	0	0	0	0	0	0	0	0	0	3	21	27	27	27	39	54	114
IMMIGRANT WORKER	0	0	0	0	0	0	0	0	0	0	6	39	50	50	50	72	99	209
IMMIGRANT SPOUSE	0	0	0	0	0	0	0	0	0	0	2	11	14	14	14	20	27	57
KETCHIKAN OFFICE																		
LOCAL	0	0	0	0	0	0	0	3	3	3	3	3	3	3	3	3	3	9
IMMIGRANT WORKER	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	6	6	17
IMMIGRANT SPOUSE	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	5
SECONDARY JOBS																		
LOCAL	0	0	0	0	0	6	6	9	17	38	66	[illegible]	107	110	108	106	92	97
IMMIGRANT WORKER	0	0	0	0	0	10	10	15	29	64	111	161	179	183	180	177	153	161
IMMIGRANT SPOUSE	0	0	0	0	0	4	4	6	11	25	44	64	72	73	72	71	61	64
VACATED LOCAL JOBS																		
LOCAL	0	0	0	0	0	2	2	3	7	15	26	37	42	42	42	41	36	39
IMMIGRANT WORKER	0	0	0	0	0	4	4	6	12	27	47	68	76	78	77	76	66	71
IMMIGRANT SPOUSE	0	0	0	0	0	1	1	2	3	7	13	19	21	21	21	21	18	19
TOTAL JOBS FILLED																		
LOCAL	0	0	0	0	0	16	16	24	47	104	181	264	294	300	296	291	254	272
IMMIGRANT WORKER	0	0	0	0	0	82	82	103	216	504	874	1174	1288	1318	1298	1196	910	576
IMMIGRANT SPOUSE	0	0	0	0	0	9	9	14	26	58	102	148	165	168	166	163	142	152
TOTAL	0	0	0	0	0	108	108	141	289	666	1157	1585	1746	1787	1760	1650	1305	1000
PROJECT INDUCED POPULATION																		
TOTAL CONSTR POPULATION	0	0	0	0	0	84	84	94	209	502	868	1108	1202	1234	1213	1066	721	146
OPERATIONS POPULATION	0	0	0	0	0	0	0	0	0	0	15	105	135	135	135	195	270	570
KETCHIKAN OFFICE POP	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	45
SECONDARY POPULATION	0	0	0	0	0	25	25	37	72	160	279	404	450	460	453	444	385	405
VACATED JOB POPULATION	0	0	0	0	0	11	11	16	31	68	110	172	192	196	193	190	166	178
TOTAL PROJ INDUCED POP	0	0	0	0	0	119	119	162	326	745	1295	1805	1994	2039	2009	1911	1557	1344
TOTAL POP W/OUT SPEC	14551	14732	14920	14920	14920	15040	15231	15273	15438	15856	16600	17109	17299	17344	17510	17412	17057	16845
SPECULATIVE IMMIGRANTS	0	0	0	0	0	25	25	33	67	155	270	368	405	414	408	381	299	220
TOTAL POPULATION	14551	14732	14920	14920	14920	15065	15256	15306	15505	16011	16870	17477	17704	17758	17918	17793	17356	17064

Temp SD
Page 2

1989				1990				1991				1992				1993			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
6408	6408	6408	6408	6490	6490	6490	6490	6573	6573	6573	6573	6657	6657	6657	6657	6742	6742	6742	6742
15699	15699	15699	15699	15900	15900	15900	15900	16104	16104	16104	16104	16310	16310	16310	16310	16518	16518	16518	16518
30	10	0	0	0	0	0	0	0	0	0	20	140	260	300	160	30	0	0	0
550	610	630	630	710	710	710	710	710	710	710	710	730	730	750	830	850	870	870	260
80	80	80	80	80	80	80	80	80	80	80	80	80	90	80	80	80	80	80	40
454	486	497	497	553	553	553	553	553	553	553	558	602	632	656	677	659	665	665	210
1134	1186	1207	1207	1343	1343	1343	1343	1343	1343	1343	1368	1552	1702	1786	1747	1619	1615	1615	510
7541	7593	7615	7615	7833	7833	7833	7833	7916	7916	7916	7941	8209	8359	8443	8404	8361	8357	8357	7252
5	1	0	0	0	0	0	0	0	0	0	2	14	26	30	16	3	0	0	0
43	9	0	0	0	0	0	0	0	0	0	17	119	221	255	136	26	0	0	0
3	1	0	0	0	0	0	0	0	0	0	1	7	13	15	8	2	0	0	0
165	183	189	189	213	213	213	213	213	213	213	213	219	219	225	249	255	261	261	78
303	336	347	347	391	391	391	391	391	391	391	391	402	402	413	457	468	479	479	143
83	92	95	95	107	107	107	107	107	107	107	107	110	110	113	125	128	131	131	39
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	12
44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	22
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	6
136	146	149	149	166	166	166	166	166	166	166	167	181	190	197	203	198	200	200	63
227	243	249	249	277	277	277	277	277	277	277	279	301	316	328	339	329	333	333	105
91	97	99	99	111	111	111	111	111	111	111	112	120	126	131	135	132	133	133	42
54	58	60	60	66	66	66	66	66	66	66	67	72	76	79	81	79	80	80	25
100	107	110	110	122	122	122	122	122	122	122	123	132	139	144	149	145	147	147	46
27	29	30	30	33	33	33	33	33	33	33	34	36	38	39	41	40	40	40	13
385	412	422	422	469	469	469	469	469	469	469	473	510	534	554	573	559	564	564	178
716	738	749	749	833	833	833	833	833	833	833	853	998	1121	1183	1124	1011	1002	1002	316
215	230	236	236	262	262	262	262	262	262	262	265	285	299	310	320	312	315	315	100
1315	1380	1406	1406	1565	1565	1565	1565	1565	1565	1565	1592	1793	1954	2048	2018	1882	1881	1821	594
52	10	0	0	0	0	0	0	0	0	0	21	146	272	314	167	31	0	0	0
824	914	944	944	1064	1064	1064	1064	1064	1064	1064	1064	1094	1094	1124	1244	1274	1304	1304	390
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	60
571	611	626	626	696	696	696	696	696	696	696	703	758	796	826	852	829	837	837	264
251	269	276	276	307	307	307	307	307	307	307	310	333	349	362	375	365	369	369	117
1819	1925	1966	1966	2187	2187	2187	2187	2187	2187	2187	2217	2452	2631	2746	2758	2620	2630	2630	831
17518	17624	17665	17665	18087	18087	18087	18087	18291	18291	18291	18321	18761	18941	19056	19068	19138	19149	19149	17349
285	299	304	304	338	338	336	338	338	338	338	344	391	429	450	440	408	407	407	128
17803	17923	17969	17969	18425	18425	18425	18425	18629	18629	18629	18665	19152	19369	19505	19508	19546	19555	19555	17477

1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008-2044
6829	6916	7004	7094	7185	7277	7370	7464	7560	7657	7657	7657	7657	7657	7657
16730	16944	17161	17381	17603	17828	18057	18288	18522	18759	18759	18759	18759	18759	18759
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
135	585	900	900	910	910	910	910	920	920	920	930	930	930	940
40	40	80	80	80	80	80	80	80	80	80	80	80	80	80
123	438	686	686	693	693	693	693	700	700	700	707	707	707	714
298	1063	1666	1666	1683	1683	1683	1683	1700	1700	1700	1717	1717	1717	1734
7126	7978	8670	8760	8868	8960	9053	9147	9260	9357	9357	9374	9374	9374	9391
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	176	270	270	273	273	273	273	276	276	276	279	279	279	282
74	322	495	495	501	501	501	501	506	506	506	512	512	512	517
20	88	135	135	137	137	137	137	138	138	138	140	140	140	141
12	12	24	24	24	24	24	24	24	24	24	24	24	24	24
22	22	44	44	44	44	44	44	44	44	44	44	44	44	44
6	6	12	12	12	12	12	12	12	12	12	12	12	12	12
37	131	206	206	208	208	208	208	210	210	210	212	212	212	214
61	219	343	343	347	347	347	347	350	350	350	354	354	354	357
25	88	137	137	139	139	139	139	140	140	140	141	141	141	143
15	53	82	82	83	83	83	83	84	84	84	85	85	85	86
27	96	151	151	153	153	153	153	154	154	154	156	156	156	157
7	26	41	41	42	42	42	42	42	42	42	42	42	42	43
104	371	582	582	588	588	588	588	594	594	594	600	600	600	606
184	659	1033	1033	1044	1044	1044	1044	1054	1054	1054	1065	1065	1065	1075
58	208	325	325	329	329	329	329	332	332	332	335	335	335	339
347	1238	1941	1941	1961	1961	1961	1961	1981	1981	1981	2000	2000	2000	2020
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
202	877	1349	1349	1364	1364	1364	1364	1379	1379	1379	1394	1394	1394	1409
60	60	120	120	120	120	120	120	120	120	120	120	120	120	120
134	551	864	864	872	872	872	872	881	881	881	890	890	890	899
68	243	381	381	385	385	385	385	388	388	388	392	392	392	396
404	1730	2713	2713	2741	2741	2741	2741	2769	2769	2769	2796	2796	2796	2824
17214	18674	19874	20094	20344	20569	20797	21029	21290	21527	21527	21555	21555	21555	21583
75	268	419	419	424	424	424	424	428	428	428	432	432	432	437
17289	18942	20294	20513	20768	20993	21221	21452	21718	21955	21955	21987	21987	21987	22019

MULTIPLIERS AND FACTORS USED IN THESE CALCULATIONS

AVGHHSZ=	2.82	VACFM=	3.30
BASESFD=	.70	PHS1SFD=	.60
BASEMFD=	.23	PHS1MFD=	.30
BASEMBL=	.07	PHS1MBL=	.10
BASESAC=	.46	PHS2SFD=	.65
CONFM=	2.30	PHS2MFD=	.25
OPRFM=	3.30	PHS2MBL=	.10
KOFM=	3.30	INMSAC=	.94
SCEFM=	3.30		

TABLE I-4B

KETCHIKAN-GATEWAY BOROUGH
HOUSING AND SCHOOL ENROLLMENT FORECAST
TEMPORARY SHUTDOWN SCENARIO

ITEM DESCRIPTION # YEAR	1983	1984	1985				1986				1987				1988			
# QTR			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
BASELINE																		
BASELINE NON-AG EMP	5937	6013	6090	6090	6090	6090	6168	6168	6168	6168	6247	6247	6247	6247	6327	6327	6327	6327
BASELINE POPULATION	14551	14732	14920	14920	14920	14920	15111	15111	15111	15111	15305	15305	15305	15305	15501	15501	15501	15501
BASELINE HOUSING TYPE																		
SINGLE FAMILY DWELLING	3612	3657	3704	3704	3704	3704	3751	3751	3751	3751	3799	3799	3799	3799	3848	3848	3848	3848
MULTI-FAMILY DWELLING	1187	1202	1217	1217	1217	1217	1232	1232	1232	1232	1248	1248	1248	1248	1264	1264	1264	1264
MOBILE DWELLING	361	366	370	370	370	370	375	375	375	375	380	380	380	380	385	385	385	385
TOTAL HOUSING UNITS	5160	5224	5291	5291	5291	5291	5359	5359	5359	5359	5427	5427	5427	5427	5497	5497	5497	5497
BSLINE SCHOOLAGE CHILDRN																		
(AVG DAILY MEMBRSHIP)	2394	2403	2434	2434	2434	2434	2465	2465	2465	2465	2497	2497	2497	2497	2528	2528	2528	2528
RESIDENCE OF PROJ IND POP																		
CONSTRUCTION POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	72	72	81	180	432	747	954	1035	1062	1044	918	621	126
KETCHIKAN/OTHER KGB	0	0	0	0	0	12	12	13	29	70	121	154	167	172	169	148	100	20
OPERATIONS POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	0	0	0	0	0	15	105	135	135	135	195	270	570
KETCHIKAN OFFICE POP																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	45
SECONDARY POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	25	25	37	72	160	279	404	450	460	453	444	385	405
VACATED LOCAL JOBS POP																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	11	11	16	31	68	110	172	192	196	193	190	166	178
TOTAL QUARTZ HILL POP	0	0	0	0	0	72	72	81	180	432	747	954	1035	1062	1044	918	621	126
TOTAL PROJ IND KGB POP	0	0	0	0	0	47	47	81	146	313	548	851	959	977	965	993	936	1218
TOTAL KGB POP (EXCL QH)	14551	14732	14920	14920	14920	14968	15159	15192	15258	15424	15853	16155	16264	16282	16466	16494	16436	16719
HOUSING TYPE IN KETCHIKAN/OTHER KGB																		
TOTAL PROJ IND HOUSING	0	0	0	0	0	17	17	29	52	111	194	302	340	347	342	352	332	432
SINGLE FAMILY DWELLING																		
PROJECT INDUCED	0	0	0	0	0	10	10	17	31	67	117	181	204	208	205	211	199	259
TOTAL	3612	3657	3704	3704	3704	3714	3761	3768	3782	3818	3916	3980	4003	4007	4053	4059	4047	4107
MULTI-FAMILY DWELLING																		
PROJECT INDUCED	0	0	0	0	0	5	5	9	16	33	58	90	102	104	103	106	100	130
TOTAL	1187	1202	1217	1217	1217	1222	1238	1241	1248	1266	1307	1339	1350	1352	1367	1370	1364	1394
MOBILE DWELLING																		
PROJECT INDUCED	0	0	0	0	0	2	2	3	5	11	19	30	34	35	34	35	33	43
TOTAL	361	366	370	370	370	372	377	378	380	386	399	410	414	415	419	420	418	428
TOTAL HOUSING UNITS	5160	5224	5291	5291	5291	5308	5375	5387	5411	5469	5622	5729	5767	5774	5839	5849	5828	5929
SCHOOLAGE CHLDRN IN KETCHIKAN/OTHER KGB (AVERAGE DAILY MEMBERSHIP)																		
FROM CONST. FAMILIES	0	0	0	0	0	5	5	5	12	29	49	63	68	70	69	61	41	8
FROM OPERATIONS FAMILIES	0	0	0	0	0	0	0	0	0	0	4	30	38	38	38	55	77	162
FROM KETCHKN OFFICE FAM	0	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	4	13
FROM SECONDARY FAMILIES	0	0	0	0	0	7	7	11	20	46	79	115	128	131	129	127	110	115
FROM VAC LOCAL JOB FAM	0	0	0	0	0	3	3	5	9	19	34	49	55	56	55	54	47	51
TOTAL PROJ IND CHILDREN	0	0	0	0	0	15	15	25	45	98	171	261	294	300	296	301	279	350
TOTAL SCHOOLAGE CHILDREN	2394	2403	2434	2434	2434	2449	2480	2490	2510	2563	2668	2758	2791	2796	2824	2830	2807	2878

1989				1990				1991				1992				1993			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
6408	6408	6408	6408	6490	6490	6490	6490	6573	6573	6573	6573	6657	6657	6657	6657	6742	6742	6742	6742
15699	15699	15699	15699	15900	15900	15900	15900	16104	16104	16104	16104	16310	16310	16310	16310	16518	16518	16518	16518
3897	3897	3897	3897	3947	3947	3947	3947	3997	3997	3997	3997	4049	4049	4049	4049	4100	4100	4100	4100
1280	1280	1280	1280	1297	1297	1297	1297	1313	1313	1313	1313	1330	1330	1330	1330	1347	1347	1347	1347
390	390	390	390	395	395	395	395	400	400	400	400	405	405	405	405	410	410	410	410
5567	5567	5567	5567	5638	5638	5638	5638	5710	5710	5710	5710	5784	5784	5784	5784	5858	5858	5858	5858
2561	2561	2561	2561	2594	2594	2594	2594	2627	2627	2627	2627	2660	2660	2660	2660	2695	2695	2695	2695
45	9	0	0	0	0	0	0	0	0	0	18	126	234	270	144	27	0	0	0
7	1	0	0	0	0	0	0	0	0	0	3	20	38	44	23	4	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
824	914	944	944	1064	1064	1064	1064	1064	1064	1064	1064	1094	1094	1124	1244	1274	1304	1304	390
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	60
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
571	611	626	626	696	696	696	696	696	696	696	703	758	796	826	852	829	837	837	264
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
251	269	276	276	307	307	307	307	307	307	307	310	333	349	362	375	365	369	369	117
45	9	0	0	0	0	0	0	0	0	0	18	126	234	270	144	27	0	0	0
1774	1916	1966	1966	2187	2187	2187	2187	2187	2187	2187	2199	2326	2397	2476	2614	2593	2630	2630	831
17473	17615	17665	17665	18087	18087	18087	18087	18291	18291	18291	18303	18635	18707	18786	18924	19111	19149	19149	17349
629	680	697	697	776	776	776	776	776	776	776	780	825	850	878	927	919	933	933	295
377	408	418	418	504	504	504	504	504	504	504	507	536	552	571	603	598	606	606	191
4274	4305	4315	4315	4451	4451	4451	4451	4501	4501	4501	4504	4585	4601	4619	4651	4698	4707	4707	4292
189	204	209	209	194	194	194	194	194	194	194	195	206	212	219	232	230	233	233	74
1469	1484	1490	1490	1491	1491	1491	1491	1507	1507	1507	1508	1536	1543	1550	1562	1577	1580	1580	1421
63	68	70	70	78	78	78	78	78	78	78	78	82	85	88	93	92	93	93	29
453	458	459	459	472	472	472	472	477	477	477	478	487	490	493	498	502	503	503	439
6196	6247	6264	6264	6414	6414	6414	6414	6486	6486	6486	6490	6608	6634	6662	6711	6777	6790	6790	6152
3	1	0	0	0	0	0	0	0	0	0	1	0	15	18	10	2	0	0	0
233	260	269	269	303	303	303	303	303	303	303	303	312	312	320	354	363	371	371	111
34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	17
163	174	178	178	198	198	198	198	198	198	198	200	216	227	235	243	236	238	238	75
72	77	79	79	87	87	87	87	87	87	87	88	95	100	103	107	104	105	105	33
506	546	560	560	623	623	623	623	623	623	623	627	665	687	711	748	739	749	749	237
3067	3107	3121	3121	3217	3217	3217	3217	3250	3250	3250	3254	3325	3348	3371	3408	3434	3444	3444	2931

1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008-2044
6829	6916	7004	7094	7185	7277	7370	7464	7560	7657	7657	7657	7657	7657	7657
16730	16944	17161	17381	17603	17828	18057	18288	18522	18759	18759	18759	18759	18759	18759
4153	4206	4260	4314	4370	4425	4482	4540	4598	4656	4656	4656	4656	4656	4656
1364	1382	1400	1418	1436	1454	1473	1492	1511	1530	1530	1530	1530	1530	1530
415	421	426	431	437	443	448	454	460	466	466	466	466	466	466
5933	6009	6085	6163	6242	6322	6403	6485	6568	6652	6652	6652	6652	6652	6652
2729	2764	2799	2835	2871	2908	2945	2983	3021	3060	3060	3060	3060	3060	3060
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
202	877	1349	1349	1364	1364	1364	1364	1379	1379	1379	1394	1394	1394	1409
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	60	120	120	120	120	120	120	120	120	120	120	120	120	120
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
154	551	864	864	872	872	872	872	881	881	881	890	890	890	899
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	243	381	381	385	385	385	385	388	388	388	392	392	392	396
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
484	1730	2713	2713	2741	2741	2741	2741	2769	2769	2769	2796	2796	2796	2824
17214	18674	19874	20094	20344	20569	20797	21029	21290	21527	21527	21555	21555	21555	21583
172	614	962	962	972	972	972	972	982	982	982	992	992	992	1001
112	399	625	625	632	632	632	632	638	638	638	645	645	645	651
4264	4605	4805	4940	5001	5057	5114	5171	5234	5295	5295	5301	5301	5301	5307
43	153	241	241	243	243	243	243	245	245	245	248	248	248	250
1407	1535	1640	1658	1679	1697	1716	1735	1756	1775	1775	1778	1778	1778	1780
17	61	96	96	97	97	97	97	98	98	98	99	99	99	100
432	482	522	528	534	540	545	551	558	564	564	565	565	565	566
6604	6622	7048	7125	7214	7294	7375	7457	7550	7634	7634	7644	7644	7644	7653
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	250	384	384	388	388	388	388	393	393	393	397	- 397	397	401
17	17	34	34	34	34	34	34	34	34	34	34	34	34	34
44	157	246	246	249	249	249	249	251	251	251	254	254	254	256
19	69	108	108	110	110	110	110	111	111	111	112	112	112	113
138	493	773	773	781	781	781	781	789	789	789	796	796	796	804
2867	3257	3572	3608	3652	3689	3726	3764	3810	3849	3849	3856	3856	3856	3864

TABLE I-5A

KETCHIKAN-GATEWAY BOROUGH
EMPLOYMENT AND POPULATION FORECAST
COMMUTE OPTION SENSITIVITY TEST 1

MULTIPLIERS AND FACTORS USED IN THESE CALCULATIONS

GRBASEMP=	.0128	SPSOPER=	.15	INMVAC=	.55
POPEMULT=	2.45	LOCKO=	.30	SPSVAC=	.15
SECMULTC=	.75	INMKO=	.55	POPPCON=	.23
SECMULTO=	.70	SPSKO	.15	POPPOPR=	1.73
LOCCON=	.35	LOCSEC=	.30	POPPKO=	1.73
INMCON=	.60	INMSEC=	.50	POPPSEC=	1.52
SPSCON=	.05	SPSSEC=	.20	POPPVAC=	1.52
LOCOPER=	.30	LOCLV=	.55	SPECINM=	.10
INMOPER=	.55	LOCVAC=	.30	POPSPEC=	1.52

ITEM DESCRIPTION YEAR	1983	1984	1985				1986				1987				1988			
QTR			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
BASELINE																		
BASELINE NON-AG EMP	5937	6013	6090	6090	6090	6090	6168	6168	6168	6168	6247	6247	6247	6247	6327	6327	6327	6327
BASELINE POPULATION	14551	14732	14920	14920	14920	14920	15111	15111	15111	15111	15305	15305	15305	15305	15501	15501	15501	15501
PROJECT EMPLOYMENT																		
CONSTRUCTION EMPLOYMENT	0	0	0	0	0	80	80	90	200	480	830	1060	1150	1180	1160	1020	690	140
OPERATIONS EMPLOYMENT	0	0	0	0	0	0	0	0	0	0	10	70	90	90	90	130	180	380
KETCHIKAN OFFICE EMPLMNT	0	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10	30
SECONDARY EMPLOYMENT	0	0	0	0	0	20	20	30	57	127	222	321	358	365	360	353	306	322
TOTAL PROJ RLTD EMPLMNT	0	0	0	0	0	100	100	130	267	617	1072	1461	1608	1645	1620	1513	1186	872
TOT NON-AG EMPLOYMENT	5937	6013	6090	6090	6090	6190	6268	6297	6435	6785	7318	7708	7854	7892	7947	7840	7512	7199
SOURCE OF EMPLOYEES																		
CONSTRUCTION																		
LOCAL	0	0	0	0	0	28	28	32	70	168	291	371	403	413	406	357	242	49
IMMIGRANT WORKER	0	0	0	0	0	48	48	54	120	288	498	636	690	708	696	612	414	84
IMMIGRANT SPOUSE	0	0	0	0	0	4	4	5	10	24	42	53	58	59	58	51	35	7
OPERATIONS																		
LOCAL	0	0	0	0	0	0	0	0	0	0	3	21	27	27	27	39	54	114
IMMIGRANT WORKER	0	0	0	0	0	0	0	0	0	0	6	39	50	50	50	72	99	209
IMMIGRANT SPOUSE	0	0	0	0	0	0	0	0	0	0	2	11	14	14	14	20	27	57
KETCHIKAN OFFICE																		
LOCAL	0	0	0	0	0	0	0	3	3	3	3	3	3	3	3	3	3	9
IMMIGRANT WORKER	0	0	0	0	0	0	0	6	6	6	6	6	6	6	6	6	6	17
IMMIGRANT SPOUSE	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	5
SECONDARY JOBS																		
LOCAL	0	0	0	0	0	6	6	9	17	38	66	96	107	110	108	106	92	97
IMMIGRANT WORKER	0	0	0	0	0	10	10	15	29	64	111	161	179	183	180	177	153	161
IMMIGRANT SPOUSE	0	0	0	0	0	4	4	6	11	25	44	64	72	73	72	71	61	64
VACATED LOCAL JOBS																		
LOCAL	0	0	0	0	0	6	6	7	15	35	60	81	89	91	90	83	64	44
IMMIGRANT WORKER	0	0	0	0	0	10	10	13	27	63	110	149	163	167	165	153	118	81
IMMIGRANT SPOUSE	0	0	0	0	0	3	3	4	7	17	36	41	45	46	45	42	32	22
TOTAL JOBS FILLED																		
LOCAL	0	0	0	0	0	40	40	51	105	244	423	572	629	644	634	588	455	313
IMMIGRANT WORKER	0	0	0	0	0	68	68	87	181	420	730	989	1087	1113	1096	1018	789	552
IMMIGRANT SPOUSE	0	0	0	0	0	11	11	15	30	68	119	170	189	193	190	184	156	155
TOTAL	0	0	0	0	0	119	119	153	317	732	1271	1731	1904	1949	1919	1791	1400	1020
PROJ INDUCED EMPLOYMENT																		
TOTAL CONSTR POPULATION	0	0	0	0	0	59	59	66	140	354	613	782	849	871	856	753	509	103
OPERATIONS POPULATION	0	0	0	0	0	0	0	0	0	0	15	105	135	135	135	195	270	570
KETCHIKAN OFFICE POP	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	45
SECONDARY POPULATION	0	0	0	0	0	25	25	37	72	160	279	404	450	460	453	444	385	405
VACATED JOB POPULATION	0	0	0	0	0	26	26	33	69	159	276	374	411	421	414	385	297	205
TOTAL PROJ INDUCED POP	0	0	0	0	0	110	110	152	303	688	1198	1681	1860	1901	1874	1792	1476	1328
TOTAL POP W/OUT SPEC	14551	14732	14920	14920	14920	15031	15222	15263	15414	15800	16503	16985	17165	17206	17374	17292	16976	16829
SPECULATIVE IMMIGRATION	0	0	0	0	0	25	25	33	67	155	270	368	405	414	408	381	299	220
TOTAL POPULATION	14551	14732	14920	14920	14920	15056	15247	15296	15482	15955	16772	17353	17569	17620	17782	17673	17275	17048

1989				1990				1991				1992				1993			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
6408	6408	6408	6408	6490	6490	6490	6490	6573	6573	6573	6573	6657	6657	6657	6657	6742	6742	6742	6742
15699	15699	15699	15699	15900	15900	15900	15900	16104	16104	16104	16104	16310	16310	16310	16310	16518	16518	16518	16518
50	10	0	0	0	0	0	0	0	0	0	20	140	260	300	160	30	0	0	0
550	610	630	630	710	710	710	710	710	710	710	710	730	730	750	830	850	870	870	900
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
454	486	497	497	553	553	553	553	553	553	553	558	602	632	656	677	659	665	665	686
1134	1186	1207	1207	1343	1343	1343	1343	1343	1343	1343	1368	1552	1702	1786	1747	1619	1615	1615	1666
7541	7593	7615	7615	7833	7833	7833	7833	7916	7916	7916	7941	8209	8359	8443	8404	8361	8357	8357	8408
18	4	0	0	0	0	0	0	0	0	0	7	49	91	105	56	11	0	0	0
30	6	0	0	0	0	0	0	0	0	0	12	84	156	180	96	18	0	0	0
3	1	0	0	0	0	0	0	0	0	0	1	7	13	15	8	2	0	0	0
165	183	189	189	213	213	213	213	213	213	213	213	219	219	225	249	255	261	261	270
303	336	347	347	391	391	391	391	391	391	391	391	402	402	413	457	468	479	479	495
83	92	95	95	107	107	107	107	107	107	107	107	110	110	113	125	128	131	131	135
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
136	146	149	149	166	166	166	166	166	166	166	167	181	190	197	203	198	200	200	206
227	243	249	249	277	277	277	277	277	277.	277	279	301.	316	328	339	329	333	333	343
91	97	99	99	111	111	111	111	111	111	111	112	120	126	131	135	132	133	133	137
57	59	60	60	66	66	66	66	66	66	66	68	78	86	91	88	80	80	80	82
104	108	110	110	122	122	122	122	122	122	122	124	143	158	167	161	147	147	147	151
28	29	30	30	33	33	33	33	33	33	33	34	39	43	45	44	40	40	40	41
399	415	422	422	469	469	469	469	469	469	469	479	551	610	642	620	567	564	564	582
707	736	749	749	833	833	833	833	833	833	833	850	973	1076	1131	1096	1006	1002	1002	1033
216	230	236	236	262	262	262	262	262	262	262	265	288	304	316	324	313	315	315	325
1322	1381	1406	1406	1565	1565	1565	1565	1565	1565	1565	1594	1812	1990	2089	2040	1886	1881	1881	1941
37	7	0	0	0	0	0	0	0	0	0	15	103	192	221	118	22	0	0	0
824	914	944	944	1064	1064	1064	1064	1064	1064	1064	1064	1094	1094	1124	1244	1274	1304	1304	1349
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
571	611	626	626	696	696	696	696	696	696	696	703	758	796	826	852	829	837	837	864
261	271	276	276	307	307	307	307	307	307	307	313	360	399	420	405	371	369	369	381
1813	1924	1966	1966	2187	2187	2187	2187	2187	2187	2187	2215	2435	2600	2711	2740	2616	2630	2630	2713
17512	17623	17665	17665	18087	18087	18087	18087	18291	18291	18291	18318	18745	18910	19021	19049	19134	19149	19149	19232
285	299	304	304	338	338	338	338	338	338	338	344	391	429	450	440	408	407	407	419
17798	17922	17969	17969	18425	18425	18425	18425	18629	18629	18629	18663	19136	19339	19470	19489	19542	19555	19555	19651

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1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008-2044
6829	6916	7004	7094	7185	7277	7370	7464	7560	7657	7657	7657	7657	7657	7657
16730	16944	17161	17381	17603	17828	18057	18288	18522	18759	18759	18759	18759	18759	18759
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	910	900	900	910	910	910	910	920	920	920	930	930	930	940
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
686	693	686	686	693	693	693	693	700	700	700	707	707	707	714
1666	1683	1666	1666	1683	1683	1683	1683	1700	1700	1700	1717	1717	1717	1734
8495	8599	8670	8760	8868	8960	9053	9147	9260	9357	9357	9374	9374	9374	9391
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
270	273	270	270	273	273	273	273	276	276	276	279	279	279	282
495	501	495	495	501	501	501	501	506	506	506	512	512	512	517
135	137	135	135	137	137	137	137	138	138	138	140	140	140	141
24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
206	208	206	206	208	208	208	208	210	210	210	212	212	212	214
343	347	343	343	347	347	347	347	350	350	350	354	354	354	357
137	139	137	137	139	139	139	139	140	140	140	141	141	141	143
82	83	82	82	83	83	83	83	84	84	84	85	85	85	86
151	153	151	151	153	153	153	153	154	154	154	156	156	156	157
41	42	41	41	42	42	42	42	42	42	42	42	42	42	43
582	588	582	582	588	588	588	588	594	594	594	600	600	600	606
1033	1044	1033	1033	1044	1044	1044	1044	1054	1054	1054	1065	1065	1065	1075
325	329	325	325	329	329	329	329	332	332	332	335	335	335	339
1941	1961	1941	1941	1961	1961	1961	1961	1981	1981	1981	2000	2000	2000	2020
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1349	1364	1349	1349	1364	1364	1364	1364	1379	1379	1379	1394	1394	1394	1409
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
864	872	864	864	872	872	872	872	881	881	881	890	890	890	899
381	385	381	381	385	385	385	385	388	388	388	392	392	392	396
2713	2741	2713	2713	2741	2741	2741	2741	2769	2769	2769	2796	2796	2796	2824
19443	19685	19874	20094	20344	20569	20797	21029	21290	21527	21527	21555	21555	21555	21583
419	424	419	419	424	424	424	424	428	428	428	432	432	432	437
19863	20109	20294	20513	20768	20993	21221	21452	21718	21955	21955	21987	21967	21987	22019

MULTIPLIERS AND FACTORS USED IN THESE CALCULATIONS			
AVGHHSZ=	2.82	VACFR=	3.30
BASESFD=	.70	PHS1SFD=	.60
BASEMFD=	.23	PHS1MFD=	.30
BASEMBL=	.07	PHS1MBL=	.10
BASESAC=	.46	PHS2SFD=	.65
CONFR=	2.30	PHS2MFD=	.25
OPRFR=	3.30	PHS2MBL=	.10
KOFR=	3.30	INMSAC=	.94
SCEFR=	3.30		

TABLE I-5B

KETCHIKAN-GATEWAY BOROUGH
HOUSING AND SCHOOL ENROLLMENT FORECAST
COMMUTE OPTION SENSITIVITY TEST 1

ITEM DESCRIPTION / YEAR	1983	1984	1985				1986				1987				1988			
QTR			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
BASELINE																		
BASELINE NON-AG EMP	5937	6013	6090	6090	6090	6090	6168	6168	6168	6168	6247	6247	6247	6247	6327	6327	6327	6327
BASELINE POPULATION	14551	14732	14920	14920	14920	14920	15111	15111	15111	15111	15305	15305	15305	15305	15501	15501	15501	15501
BASELINE HOUSING TYPE																		
SINGLE FAMILY DWELLING	3612	3657	3704	3704	3704	3704	3751	3751	3751	3751	3799	3799	3799	3799	3848	3848	3848	3848
MULTI-FAMILY DWELLING	1187	1202	1217	1217	1217	1217	1232	1232	1232	1232	1248	1248	1248	1248	1264	1264	1264	1264
MOBILE DWELLING	361	366	370	370	370	370	375	375	375	375	380	380	380	380	385	385	385	385
TOTAL HOUSING UNITS	5160	5224	5291	5291	5291	5291	5359	5359	5359	5359	5427	5427	5427	5427	5497	5497	5497	5497
BSLINE SCHOOLAGE CHILDRN (AVG DAILY MEMBRSHIP)	2394	2403	2434	2434	2434	2434	2465	2465	2465	2465	2497	2497	2497	2497	2528	2528	2528	2526
RESIDENCE OF PROJ IND POP																		
CONSTRUCTION POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	52	52	59	130	312	540	689	748	767	754	663	449	91
KETCHIKAN/OTHER KGB	0	0	0	0	0	7	7	8	18	42	73	93	101	104	102	90	61	12
OPERATIONS POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	0	0	0	0	0	15	105	135	135	135	195	270	570
KETCHIKAN OFFICE POP																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	0	0	15	15	15	15	15	15	15	15	15	15	45
SECONDARY POPULATION																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	25	25	37	72	160	279	404	450	460	453	444	385	405
VACATED LOCAL JOBS POP																		
QUARTZ HILL SITE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KETCHIKAN/OTHER KGB	0	0	0	0	0	26	26	33	69	159	276	374	411	421	414	385	297	205
TOTAL QUARTZ HILL POP	0	0	0	0	0	52	52	59	130	312	540	689	748	767	754	663	449	91
TOTAL PROJ IND KGB POP	0	0	0	0	0	58	58	93	173	376	658	992	1112	1134	1120	1129	1027	1237
TOTAL KGB POP (EXCL QH)	14551	14732	14920	14920	14920	14979	15170	15204	15284	15488	15963	16296	16417	16439	16620	16629	16528	16732
HOUSING TYPE IN KETCHIKAN/OTHER KGB																		
TOTAL PROJ IND HOUSING	0	0	0	0	0	21	21	33	61	133	233	352	394	402	397	400	364	439
SINGLE FAMILY DWELLING																		
PROJECT INDUCED	0	0	0	0	0	12	12	20	37	80	140	211	237	241	238	240	219	263
TOTAL	3612	3657	3704	3704	3704	3716	3763	3771	3788	3831	3939	4010	4036	4040	4086	4088	4066	4111
MULTI-FAMILY DWELLING																		
PROJECT INDUCED	0	0	0	0	0	6	6	10	18	40	70	105	118	121	119	120	109	132
TOTAL	1187	1202	1217	1217	1217	1223	1239	1242	1251	1273	1318	1354	1367	1369	1383	1384	1374	1396
MOBILE DWELLING																		
PROJECT INDUCED	0	0	0	0	0	2	2	3	6	13	23	35	39	40	40	40	36	44
TOTAL	361	366	370	370	370	372	377	378	381	388	403	415	419	420	424	425	421	429
TOTAL HOUSING UNITS	5160	5224	5291	5291	5291	5312	5379	5392	5420	5492	5661	5779	5822	5829	5894	5897	5861	5935
SCHOOLAGE CHLDRN IN KETCHIKAN/OTHER KGB (AVERAGE DAILY MEMBERSHIP)																		
FROM CONST. FAMILIES	0	0	0	0	0	3	3	3	7	17	30	38	41	42	42	37	25	5
FROM OPERATIONS FAMILIES	0	0	0	0	0	0	0	0	0	0	4	30	38	38	38	35	77	162
FROM KETCHKN OFFICE FAM	0	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	4	13
FROM SECONDARY FAMILIES	0	0	0	0	0	7	7	11	20	46	75	115	128	131	129	127	110	115
FROM VAC LOCAL JOB FAM	0	0	0	0	0	7	7	9	20	45	79	107	117	120	118	110	85	58
TOTAL PROJ IND CHILDREN	0	0	0	0	0	17	17	27	51	112	197	294	329	336	332	333	300	354
TOTAL SCHOOLAGE CHILDREN	2394	2403	2434	2434	2434	2451	2482	2492	2516	2577	2693	2791	2826	2832	2860	2861	2829	2880

1989				1990				1991				1992				1993			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
6408	6408	6408	6408	6490	6490	6490	6490	6573	6573	6573	6573	6657	6657	6657	6657	6742	6742	6742	6742
15699	15699	15699	15699	15900	15900	15900	15900	16104	16104	16104	16104	16310	16310	16310	16310	16518	16518	16518	16518
3897	3897	3897	3897	3947	3947	3947	3947	3997	3997	3997	3997	4049	4049	4049	4049	4100	4100	4100	4100
1280	1280	1280	1280	1297	1297	1297	1297	1313	1313	1313	1313	1330	1330	1330	1330	1347	1347	1347	1347
390	390	390	390	395	395	395	395	400	400	400	400	405	405	405	405	410	410	410	410
5567	5567	5567	5567	5638	5638	5638	5638	5710	5710	5710	5710	5784	5784	5784	5784	5858	5858	5858	5858
2561	2561	2561	2561	2594	2594	2594	2594	2627	2627	2627	2627	2660	2660	2660	2660	2695	2695	2695	2695
33	7	0	0	0	0	0	0	0	0	0	13	91	169	195	104	20	0	0	0
4	1	0	0	0	0	0	0	0	0	0	2	12	23	26	14	3	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
824	914	944	944	1064	1064	1064	1064	1064	1064	1064	1064	1094	1094	1124	1244	1274	1304	1304	1349
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
571	611	626	626	696	696	696	696	696	696	696	703	758	796	826	852	829	837	837	864
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
261	271	276	276	307	307	307	307	307	307	307	313	360	399	420	405	371	369	369	381
33	7	0	0	0	0	0	0	0	0	0	13	91	169	195	104	20	0	0	0
1780	1918	1966	1966	2187	2187	2187	2187	2187	2187	2187	2202	2344	2431	2516	2636	2597	2638	2630	2713
17480	17617	17665	17665	18087	18087	18087	18087	18291	18291	18291	18305	18654	18741	18826	18945	19115	19149	19149	19232
631	680	697	697	776	776	776	776	776	776	776	781	831	862	892	935	921	933	933	962
379	408	418	418	504	504	504	504	504	504	504	507	540	560	580	607	598	606	606	625
4276	4305	4315	4315	4451	4451	4451	4451	4501	4501	4501	4505	4589	4609	4628	4656	4699	4707	4707	4726
189	204	209	209	194	194	194	194	194	194	194	195	208	216	223	234	230	233	233	241
1470	1484	1490	1490	1491	1491	1491	1491	1507	1507	1507	1509	1538	1546	1553	1564	1577	1580	1580	[illegible]
63	68	70	70	78	78	78	78	78	78	78	78	83	86	89	93	92	93	93	96
453	458	459	459	472	472	472	472	477	477	477	478	488	491	494	498	502	505	503	506
6198	6247	6264	6264	6414	6414	6414	6414	6486	6486	6486	6491	6615	6646	6676	6710	6778	6790	6790	6829
2	0	0	0	0	0	0	0	0	0	0	1	5	9	11	6	1	0	0	0
235	260	269	269	303	303	303	303	303	303	303	303	312	312	320	354	363	371	371	384
34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
163	174	178	178	198	198	198	198	198	198	198	200	216	227	235	243	236	238	238	246
74	77	79	79	87	87	87	87	87	87	87	89	103	114	120	115	106	105	105	108
508	546	560	560	623	623	623	623	623	623	623	627	669	695	720	752	740	749	749	773
3069	3107	3121	3121	3217	3217	3217	3217	3250	3250	3250	3254	3330	3356	3380	3413	3434	3444	3444	3467

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008-2044
	6829	6916	7004	7094	7185	7277	7370	7464	7560	7657	7657	7657	7657	7657	7657
	16730	16944	17161	17381	17603	17828	18057	18288	18522	18759	18759	18759	18759	18759	18759
	4153	4206	4260	4314	4370	4425	4482	4540	4598	4656	4656	4656	4656	4656	4656
	1364	1382	1400	1418	1436	1454	1473	1492	1511	1530	1530	1530	1530	1530	1530
	415	421	426	431	437	443	448	454	460	466	466	466	466	466	466
	5933	6009	6085	6163	6242	6322	6403	6485	6568	6652	6652	6652	6652	6652	6652
	2729	2764	2799	2835	2871	2908	2945	2983	3021	3060	3060	3060	3060	3060	3060
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1349	1364	1349	1349	1364	1364	1364	1364	1379	1379	1379	1394	1394	1394	1409
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	864	872	864	864	872	872	872	872	881	881	881	890	890	890	899
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	381	385	381	381	385	385	385	385	388	388	388	392	392	392	396
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2713	2741	2713	2713	2741	2741	2741	2741	2769	2769	2769	2796	2796	2796	2824
	19443	19685	19874	20094	20344	20569	20797	21029	21290	21527	21527	21553	21555	21555	21583
	962	972	962	962	972	972	972	972	982	982	982	992	992	992	1001
	625	632	625	625	632	632	632	632	638	638	638	645	645	645	651
	4778	4830	4885	4940	5001	5057	5114	5171	5236	5295	5295	5301	5301	5301	5307
	241	243	241	241	243	243	243	243	245	245	245	248	248	248	250
	1605	1625	1640	1658	1679	1697	1716	1735	1756	1775	1775	1778	1778	1778	1780
	96	97	96	96	97	97	97	97	98	98	98	99	99	99	100
	501	510	522	528	534	540	545	551	558	564	564	565	565	565	566
	6895	6980	7048	7125	7214	7294	7375	7457	7530	7634	7634	7644	7644	7644	7653
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	384	388	384	384	388	388	388	388	393	393	393	397	397	397	401
	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
	246	249	246	246	249	249	249	249	251	251	251	254	254	254	256
	108	110	108	108	110	110	110	110	111	111	111	112	112	112	113
	773	781	773	773	781	781	781	781	789	789	789	796	796	796	804
	3502	3545	3572	3608	3652	3689	3726	3764	3810	3849	3849	3856	3856	3856	3864

TABLE I-6

ASSUMPTIONS USED IN POPULATION AND EMPLOYMENT PROJECTIONS, KETCHIKAN GATEWAY BOROUGH

Multiplier and Factor Name	Value	Data Source
GRBASEMP - Annual baseline economic growth rate (percent)	1.28	Richard Morehouse & Associates. 1983. Managing Social Impacts.
POPEMULT - Population to employment ratio	2.45	Envirosphere in conjunction with KGB
SECMULTC - Secondary employment multiplier, construction phase	.25	Leistritz, Murdock, & Leholm. 1982. In: Weber and Howell, eds. Coping with Rapid Growth in Rural Communities
SECMULTO - Secondary employment multiplier, operations phase	.70	
LOCCON - Percentage of construction work force filled by local (KGB) residents	.10 1/ .35 2/	Envirosphere Amoco - Thompson Creek Molybdenum Mine Ketchikan Job Service
INMCON - Percentage of construction work force filled by in-migrating workers	.85 1/ .65 2/	Envirosphere
SPSCON - Percentage of construction work force filled by spouses of in-migrants	.05 1/ .05 2/	Envirosphere
LOCOPER - Percentage of operations work force filled by local (KGB) residents	.30	Envirosphere Amoco - Thompson Creek Molybdenum Mine
INMOPER - Percentage of operations work force filled by in-migrating workers	.55	Envirosphere
SPSOPER - Percentage of operations work force filled by spouses of in-migrants	.15	Envirosphere
LOCKO - Percentage of Ketchikan office personnel filled by local (KGB) residents	.30	Envirosphere

1/ Commute, Townsite, Temporary Shutdown, Phase-In options.
2/ Commute Sensitivity Test.

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TABLE I-6 (Con't)

Multiplier and Factor Name	Value	Data Source
INMKO - Percentage of Ketchikan office personnel filled by in-migrating workers	.55	Envirosphere
SPSKO - Percentage of Ketchikan office personnel filled by spouses of in-migrants	.15	Envirosphere
LOCSEC - Percentage of secondary jobs filled by local (KGB) residents	.30	Envirosphere Halstead and Leistritz. 1983. Impacts of Energy Development on Secondary Labor Markets: A Study of Seven Western Counties.
INMSEC - Percentage of secondary jobs filled by in-migrating workers	.50	
SPSSEC - Percentage of secondary jobs filled by spouses of in-migrants	.20	
LOCLV - Percent of local residents hired (all categories) who were already employed in local area	.55	Envirosphere
LOCVAC - Percentage of vacated local jobs filled by local residents	.30	Envirosphere
INMVAC - Percentage of vacated local jobs filled by in-migrants	.55	Envirosphere
SPSVAC - Percentage of vacated local jobs filled by spouses of in-migrants	.15	Envirosphere
POPPCON - Percentage of in-migrating married construction workers with family members present (.10) X number of dependents per married worker (2.3)	.23	Workers bringing families: Amoco - Thompson Creek Molybdenum Mine S.J. Groves - General Contractor for Swan Lake Hydroelectric Project Household Size: Electric Power Research Institute. 1982. Socioeconomic Impacts of Power Plants.
POPPOPR - Percentage of in-migrating married operations workers with family members present (.75) X number of dependents per married worker (2.3)	1.73	
POPPKO - Percentage of in-migrating married Ketchikan office workers with family members present (.75) X number of dependents per married worker (2.3)	1.73	

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TABLE I-6 (Con't)

Multiplier and Factor Name	Value	Data Source
POPPSEC - Percentage of in-migrating married secondary workers with family members present (.66) X number of dependents per married worker (2.3)	1.52	Halstead and Leistritz. 1983. Impacts of Energy Development on Secondary Labor Markets: A Study of of Seven Western Counties
POPPVAC - Percentage of married in-migrating workers filling vacated local jobs with family members present (.66) X number of dependents per married worker (2.3)	1.52	Envirosphere
SPECINM - Speculative in-migrants who do not find any job, as a percentage of total project-related employment	.10	Envirosphere
POPSPEC - Percentage of married speculative in-migrants with family members present (.66) x number of dependents per married in-migrant (2.3)	1.52	Envirosphere

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TABLE I-7

ASSUMPTIONS USED IN HOUSING AND SCHOOL ENROLLMENT FORECAST, KETCHIKAN GATEWAY BOROUGH

Multiplier and Factor Name	Value	Data Source
AVGHHSZ - Average household size	2.82	KGB Planning Department
BASESFD - Baseline single family dwellings (percent)	70	KGB Planning Department
BASEMFD - Baseline multi-family dwellings (percent)	23	KGB Planning Department
BASEMBL - Baseline mobile dwellings (percent)	7	KGB Planning Department
BASESAC - Baseline school age children per housing unit	.46	Envirosphere - based on 1983 ratio of 2394 average daily membership and 5160 housing units
CONFM - Dependents per married in-migrating construction worker with family members present	2.3	Electric Power Research Institute. 1982. Socioeconomic Impacts of Power Plants.
OPRFM - Total household size per married in-migrating operations worker with family members present	3.3	Electric Power Research Institute. 1982. Socioeconomic Impacts of Power Plants.
KOFM - Total household size per married in-migrating Ketchikan office worker with family members present	3.3	Electric Power Research Institute. 1982. Socioeconomic Impacts of Power Plants.
SECFM - Total household size per married in-migrating secondary worker with family members present	3.3	Electric Power Research Institute. 1982. Socioeconomic Impacts of Power Plants.
VACFM - Total household size per married in-migrating worker filling vacated local job, with family members present	3.3	Electric Power Research Institute. 1982. Socioeconomic Impacts of Power Plants.

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TABLE I-7 (Con't)

Multiplier and Factor Name	Value	Data Source
PHS1SFD - Single family dwellings for first five years of project (percent)	60	KGB Planning Department
PHS1MFD - Multi-family dwellings for first five years of project (percent)	30	KGB Planning Department
PHS1MBL - Mobile dwellings for first five years of project (percent)	10	KGB Planning Department
PHS2SFD - Single family dwellings during sixth and following years of project (percent)	65	KGB Planning Department
PHS2MFD - Multi-family dwellings during sixth and following years of project (percent)	25	KGB Planning Department
PHS2MBL - Mobile dwellings during sixth and following years of project (percent)	10	KGB Planning Department
INMSAC - Number of children per in-migrating worker with family members present (1.3) X percent of children under 18 in grades K-12 (13/18)	.94	Envirosphere

TABLE I-8

KETCHIKAN GATEWAY BOROUGH
EQUATIONS USED IN EMPLOYMENT
AND POPULATION FORECAST

Line Number	Item Description	Equation
BASELINE		
(1)	Baseline Non-Ag Emp	5937 in 1983 growing at GRBASEMP per year thru 2003; constant thereafter
(2)	Baseline Population	14,551 in 1983; other years = POPEMULT x Line 1
PROJECT EMPLOYMENT		
(3)	Construction Employment	Defined by scenario
(4)	Operations Employment	Defined by scenario
(5)	Ketchikan Office Emp.	Defined by scenario
(6)	Secondary Emp.	(SECMULTC x Line 3) + (SECMULTO x Line 4) + SECMULTO x Line 5)
(7)	Total Project-Related Emp.	Line 3 + Line 4 + Line 5 + Line 6
(8)	Total Non-Ag Emp.	Line 1 + Line 7
SOURCE OF EMPLOYEES		
(9)	Local	Line 3 x LOCCON
(10)	In-migrant	Line 3 x INCON
(11)	Spouse	Line 3 x SPSCON
OPERATIONS		
(12)	Local	Line 4 x LOCOPER
(13)	In-migrant	Line 4 x INMOPER
(14)	Spouse	Line 4 x SPSOPER

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Line Number	Item Description	Equation
KETCHIKAN OFFICE		
(15)	Local	Line 5 x LOCKO
(16)	In-migrant	Line 5 x INMKO
(17)	Spouse	Line 5 x SPSKO
SECONDARY JOBS		
(18)	Local	Line 6 x LOCSEC
(19)	In-migrant	Line 6 x INMSEC
(20)	Spouse	Line 6 x SPSSEC
VACATED LOCAL JOBS		
(21)	Local	(Line 9 + Line 12 + Line 15 + Line 18) x LOCLV x LOCVAC
(22)	In-migrant	(Line 9 + Line 12 + Line 15 + Line 18) x LOCLV x INMVAC
(23)	Spouse	(Line 9 + Line 12 + Line 15 + Line 18) x LOCLV x SPSVAC
TOTAL JOBS FILLED		
(24)	Local	Line 9 + Line 12 + Line 15 + Line 18 + Line 21
(25)	In-migrant	Line 10 + Line 13 + Line 16 + Line 19 + Line 22
(26)	Spouse	Line 11 + Line 14 + Line 17 + Line 20 + Line 23
(27)	Total	Line 24 + Line 25 + Line 26

Line Number	Item Description	Equation
PROJECT-INDUCED POPULATION		
(28)	Total Construction Pop.	Line 10 + (Line 10 x POPPCON)
(29)	Operations Population	Line 13 + (Line 13 x POPPOPR)
(30)	Ketckikan Office Pop.	Line 16 + (Line 16 x POPPKO)
(31)	Secondary Population	Line 19 + (Line 19 x POPPSEC)
(32)	Vacated Job Population	Line 22 + (Line 22 x POPPVAC)
(33)	Total Project-Induced Population	Line 28 + Line 29 + Line 30 + Line 31 + Line 32
(34)	Total Population Without Speculative In-Migrants	Line 2 + Line 33
(35)1/	Speculative In-Migrants	(Line 7 x SPECINM) + (Line 7 x SPECINM x POPSPEC)
(36)	Total Population	Line 34 + Line 35

1/ This calculation is used only to estimate Line 36. It is not used in subsequent calculations of households, residences, or school age children.

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TABLE I-9

KETCHIKAN GATEWAY BOROUGH
EQUATIONS USED IN HOUSING AND
SCHOOL ENROLLMENT FORECAST

Line Number	Item Description	Equation
BASELINE		
(37)	Baseline Non-Ag Emp.	Same as Line 1
(38)	Baseline Population	Same as Line 2
BASELINE HOUSING TYPE		
(39)	Single Family Dwelling	Line 8/AVGHHSZ x BASESFD
(40)	Multi-Family Dwelling	Line 8/AVGHHSZ x BASEMFD
(41)	Mobile Dwelling	Line 8/AVGHHSZ x BASEMBL
(42)	Total Housing Units	Line 39 + Line 40 + Line 41 (also Line 38/AVGHHSZ)
BASELINE SCHOOL AGE CHILDREN		
(43)	Baseline School Age Children (Avg Daily Membership)	2394 in 1983; other years = Line 42 x BASEADM
RESIDENCE OF PROJECT-INDUCED POPULATION		
Construction Population		
(44)	Quartz Hill Site	Line 10 + Line 11
(45)	Ketchikan/Other KGB	Line 28 - Line 44
Operations Population		
(46)	Quartz Hill Site	Defined by scenario - see Table I-10
(47)	Ketchikan/Other KGB	Defined by scenario - see Table I-10

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TABLE I-9 (Con't)

Line Number	Item Description	Equation
Ketchikan Office Population		
(48)	Quartz Hill Site	Zero
(49)	Ketchikan/Other KGB	Line 30
Secondary Population		
(50)	Quartz Hill Site	Defined by scenario - see Table I-10
(51)	Ketchikan/Other KGB	Defined by scenario - see Table I-10
Vacated Local Jobs Population		
(52)	Quartz Hill Site	Zero
(53)	Ketchikan/Other KGB	Line 32
Total Population		
(54)	Quartz Hill Site	Line 44 + Line 46 + Line 48 + Line 50 + Line 52
(55)	Proj-Ind Ketchikan/KGB	Line 45 + Line 47 + Line 49 + Line 51 + Line 53
(56)	Total Ketchikan/KGB (excluding Quartz Hill Site)	Line 38 + Line 55 (also Line 34 - Line 54)
HOUSING TYPE IN KETCHIKAN/OTHER KGB		
(57)	Total Project-Induced Housing	Line 55/AVGHHSZ
Single Family Dwellings		
(58)	Project-Induced	1985-1989: Line 57 x PHS1SFD 1990-2044: Line 57 x PHS2SFD
(59)	Total	Line 39 + Line 58

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TABLE I-9 (Con't)

Line Number	Item Description	Equation
Multi-Family Dwellings		
(60)	Project-Induced	1985-1989: Line 57 x PHS1MFD 1990-2044: Line 57 x PHS2MFD
(61)	Total	Line 40 + Line 60
Mobile Dwellings		
(62)	Project-Induced	1985-1989: Line 57 x PHS1MBL 1990-2044: Line 57 x PHS2MBL
(63)	Total	Line 41 + Line 62
Total		
(64)	Total Housing Units	Line 59 + Line 61 + Line 63 (also Line 42 + Line 57)
SCHOOL AGE CHILDREN IN KETCHIKAN/OTHER KGB (Average Daily Membership)		
(65)	From Construct. Families	Line 45/CONFM x INMSAC
(66)	From Operations Families	Line 47/OPRFM x INMSAC
(67)	From Ketch. Office Fam.	Line 49/KOFM x INMSAC
(68)	From Secondary Families	Line 51/SECFM x INMSAC
(69)	From Vac. Loc. Job Fam.	Line 53/VACFM x INMSAC
(70)	Total Project-Induced School Age Children	Line 65 + Line 66 + Line 67 + Line 68 + Line 69
(71)	Total School Age Children	Line 43 + Line 70

TABLE I-10

LOCATION OF PROJECT-INDUCED POPULATION

Option	Construction Population	Operations Population	Ketchikan Office Population	Secondary Population	Vacated Job Population
Commute	QH-in-migrant workers and working spouses KGB-family less spouses working at site	KGB	KGB	KGB	KGB
Townsite	QH-in-migrant workers and working spouses KGB-family less spouses working at site	KGB 1987-1988 QH 1989-2044	KGB	KGB 1987-88 Number of workers plus families locating at Quartz Hill site: 1989-100 + (100xPOPPSEC)1/ 1990-120 + (120xPOPPSEC) 1991-150 + (150xPOPPSEC) 1992-180 + (180xPOPPSEC) 1993-210 + (210xPOPPSEC) 1994-2044-240+ (240xPOPPSEC)	KGB

QH - Quartz Hill
KGB - Ketchikan Gateway Borough

1/ POPPSEC = population per in-migrating secondary worker
= percent of workers bringing families (.66) x number of dependents per worker (2.3)
= 1.52

1055K

TABLE I-10 (Con't)

Option	Construction Population	Operations Population	Ketchikan Office Population	Secondary Population	Vacated Job Population
				Number of workers plus families locating in Ketchikan/ Other KGB: 1989-2044- Secondary population less those locating at Quartz Hill site	
Phase-In Townsite	QH-in-migrant workers and working spouses KGB-family less spouses working at site	KGB 1987-1991(2) Rate of relocation to QH 1991(3) 7% 1991(4) 14% 1992(1) 21% 1992(2) 27% 1992(3) 33% 1992(4) 36% 1993(1) 44% 1993(2) 52% 1993(3) 60% 1993(4) 67% 1994 100%	KGB	KGB 1987-88 1989-2044 Same as Townsite Option	KGB
Temporary Shutdown	QH-in-migrant workers and working spouses KGB-family less spouses working at site	KGB	KGB	KGB	KGB

TABLE I-11

COMMUTE SCENARIO
WORK FORCE FOR QUARTZ HILL PROJECT

Year/Quarter		Construction[1/]	Quartz Hill Operations	Ketchikan Office	Total
-4	4	80			80
-3	1	80			80
	2	90		10	100
	3	200		10	210
	4	480		10	490
-2	1	830	10	10	850
	2	1060	70	10	1140
	3	1150	90	10	1250
	4	1180	90	10	1280
-1	1	1160	90	10	1260
	2	1020	130	10	1160
	3	690	180	10	880
	4	140	380	30	550
Startup					
1	1	50	550	80	680
	2	10	610	80	700
	3		630	80	710
	4		630	80	710
2	1		710	80	790
	2		710	80	790
	3		710	80	790
	4		710	80	790
3	1		710	80	790
	2		710	80	790
	3		710	80	790
	4	20	710	80	810

1/ Includes subcontractors such as camp catering and housekeeping.

1055K

TABLE I-11 (Continued)

COMMUTE SCENARIO

WORK FORCE FOR QUARTZ HILL PROJECT

Year/Quarter		Construction[1/]	Quartz Hill Operations	Ketchikan Office	Total
4	1	140	730	80	950
	2	260	730	80	1070
	3	300	750	80	1130
	4	160	830	80	1070
Expansion to 80,000 tpd					
5	1	30	850	80	960
	2		870	80	950
	3		870	80	950
	4		900	80	980
6			900	80	980
7			910	80	990
8			900	80	980
9			900	80	980
10-13			910	80	990
14-16			920	80	1000
17-19			930	80	1010
20			940	80	1020

1055K

TABLE I-11 (Continued)

PHASE-IN SCENARIO

WORK FORCE FOR QUARTZ HILL PROJECT

Year/Quarter		Construction1/	Townsite Construction Workers	Quartz Hill Operations	Ketchikan Office	Total
-4	4	80				80
-3	1	80				80
	2	90			10	100
	3	200			10	210
	4	480			10	490
-2	1	840		10	10	860
	2	1060		70	10	1140
	3	1150		90	10	1250
	4	1180		90	10	1280
-1	1	1160		90	10	1260
	2	1020		130	10	1160
	3	690		180	10	880
	4	140		380	30	550
Startup						
1	1	50	50	550	80	730
	2	10	60	610	80	760
	3		70	630	80	780
	4		100	630	80	810
2	1		100	710	80	890
	2		100	710	80	890
	3		100	710	80	890
	4		100	710	80	890
3	1		100	710	80	890
	2		100	710	80	890
	3		100	710 ô 50	80	890
	4	20	100	710 ô 50	80	910

1/ Includes subcontractors such as camp catering and housekeeping.

1055K

TABLE I-11 (Continued)

PHASE-IN SCENARIO

WORK FORCE FOR QUARTZ HILL PROJECT

Year	Quarter	Construction1/	Townsite Construction Workers	Quartz Hill Operations	Ketchikan Office	Total
4	1	140	100	730 ô 50	80	1050
	2	260	70	730 ô 50	80	1140
	3	300	60	750 ô 50	80	1190
	4	160	50	830 ô 50	80	1120
Expansion to 80,000 tpd						
5	1	30		850 ô 75	80	960
	2			870 ô 75	80	950
	3			870 ô 75	80	950
	4			900 ô 75	80	980
6				900 ô 300	80	980
7				910	80	990
8				900	80	980
9				900	80	980
10-13				910	80	990
14-16				920	80	1000
17-19				930	80	1010
20				940	80	1020

1055K

TABLE I-11 (Continued)

TOWNSITE SCENARIO

WORK FORCE FOR QUARTZ HILL PROJECT

Year	Quarter	Construction[1/]	Townsite Construction Workers	Quartz Hill Operations	Ketchikan Office	Total
-4	4	80				80
-3	1	80				80
	2	90			10	100
	3	200			10	210
	4	470			10	480
-2	1	840		10	10	860
	2	1060	100	70	10	1240
	3	1150	200	90	10	1450
	4	1180	250	90	10	1530
-1	1	1160	250	90	10	1510
	2	1020	250	130	10	1410
	3	690	200	180	10	1080
	4	140	100	380	30	650
Startup						
1	1	50		550	80	680
	2	10		610	80	700
	3			630	80	710
	4			630	80	710
2	1			710	80	790
	2			710	80	790
	3			710	80	790
	4			710	80	790
3	1			710	80	790
	2			710	80	790
	3			710	80	790
	4	20		710	80	810

1/ Includes subcontractors such as camp catering and housekeeping.

1055K

TABLE I-11 (Continued)

TOWNSITE SCENARIO

WORK FORCE FOR QUARTZ HILL PROJECT

Year/Quarter		Constsuction[1/]	Townsite Construction Workers	Quartz Hill Operations	Ketchikan Office	Total
4	1	140		730	80	950
	2	260		730	80	1070
	3	300		750	80	1130
	4	160		830	80	1070
Expansion to 80,000 tpd						
5	1	30		850	80	960
	2			870	80	950
	3			870	80	950
	4			900	80	980
6				900	80	980
7				910	80	990
8				900	80	980
9				900	80	980
10-13				910	80	990
14-16				920	80	1000
17-19				930	80	1010
20				940	80	1020

1055K

TABLE I-11 (Continued)

TEMPORARY SHUTDOWN SCENARIO

WORK FORCE FOR QUARTZ HILL PROJECT

Year/Quarter		Construction1/	Quartz Hill Operations	Ketchikan Office	Total
-4	4	80			80
-3	1	80			80
	2	90		10	100
	3	200		10	210
	4	480		10	490
-2	1	830	10	10	850
	2	1060	70	10	1140
	3	1150	90	10	1250
	4	1180	90	10	1280
-1	1	1160	90	10	1260
	2	1020	130	10	1160
	3	690	180	10	880
	4	140	380	30	550
Startup					
1	1	50	550	80	680
	2	10	610	80	700
	3		630	80	710
	4		630	80	710
2	1		710	80	790
	2		710	80	790
	3		710	80	790
	4		710	80	790
3	1		710	80	790
	2		710	80	790
	3		710	80	790
	4	20	710	80	810

1/ Includes subcontractors such as camp catering and housekeeping.

1055K

TABLE I-11 (Continued)

TEMPORARY SHUTDOWN SCENARIO

WORK FORCE FOR QUARTZ HILL PROJECT

Year/Quarter		Construction[1]	Quartz Hill Operations	Ketchikan Office	Total
4	1	140	730	80	950
	2	260	730	80	1070
	3	300	750	80	1130
	4	160	830	80	1070
Expansion to 80,000 tpd					
5	1	30	850	80	960
	2		870	80	950
	3		870	80	950
Shutdown	4		260	40	300
6			135	40	175
7			585	40	625
8			900	80	980
9			900	80	980
10-13			910	80	990
14-16			920	80	1000
17-19			930	80	1010
20			940	80	1020

1055K

AGREED DISCUSSION PROCEDURE
AND MEMORANDUM OF UNDERSTANDING
BETWEEN KETCHIKAN COMMUNITIES AND US BORAX
RELATING TO IMPACT OF
QUARTZ HILL MOLYBDENUM MINE DEVELOPMENT
ON KETCHIKAN AREA COMMUNITIES

5018A

AGREED PROCEDURE FOR

KETCHIKAN COMMUNITY/U.S. BORAX DISCUSSIONS

The following is a step-by-step procedure for future continuation of the discussion with the Ketchikan area Communities regarding potential socioeconomic impacts of the Quartz Hill Project. This procedure has been agreed upon between the Community representatives and U.S. Borax.

Joint discussions have indicated that resolutions of impacts will still best be addressed on an issue-by-issue basis. The discussions have also indicated there are some issues which cannot be fully resolved at the present time, and that some agreements will be preliminary in nature, with refinements being made at a time closer to the start of construction when the current baseline community conditions are known.

The Community and U.S. Borax agree that those issues that can be resolved now on an individual basis should be addressed and agreed upon now. Both parties propose to continue discussions for agreement on these issues and will adopt the procedure outlined herein for getting on with this task.

PROCEDURE

1. The Community and U.S. Borax will try to agree first on a Memorandum of Understanding (MOU) to set the framework for further discussion on individual items.

2. An initial meeting will be held to review the division of discussion issues into three categories (A. - Can be Resolved Now, B. - Cannot be Fully Resolved Now, C. - Don't Understand) and to set an order of priority for Category A. It is the intention of the Community and U.S. Borax to discuss and to come to at least a preliminary agreement on all listed issues, with such agreement to be included in the U.S. Forest Service's Record of decision.

3. A series of ad-hoc meetings will be held to discuss Category A subjects one or two at a time. The establishment of a monitoring program (for socioeconomic indicators) will be one of the first items discussed.

4. At the same time, the Community will supply clarification of items in the "Don't Understand" category. As these items are clarified, they will be reclassified into Categories A or B.

5. To promote internal communications, USB's Ketchikan Manager will write brief internal reports on each meeting giving

date, those attending, subjects discussed, conclusions reached (if any), his perception of issues discussed and his early recommendations regarding development of any corporate positions which may be required. USB's Vice President and Project Manager will circulate these reports to the appropriate persons within U.S. Borax.

6. The Ketchikan Manager will be the principal avenue for communication of U.S. Borax positions to the Community representatives by way of the ad-hoc meetings.

7. As proposals or suggestions on individual items emerge from the meetings, they will be reduced to writing. U.S. Borax will draft tentative solutions and/or corporate positions. These will be circulated within U.S. Borax for further comment and approval.

8. The results of Step 7 will be conveyed to the Community by U.S. Borax's Ketchikan Manager at the meeting next following for further discussion or tentative approval by the Community representatives.

9. Tentative concurrence on each issue will be recorded as a "Memorandum of Tentative Agreement."

10. No agreement will be considered final until approved by the three elected bodies and the President of U.S. Borax.

11. In order to maintain control of the Project's total financial obligation, final approval on issues requiring more than a nominal financial commitment will be deferred until the bulk of the issues have been discussed.

12. For the near future, discussions will concentrate on the issues in the "Can be Resolved Now" Category. A primary goal will be the resolution of as many issues as possible in time for the Final EIS.

<u>General</u>

The above procedure contemplates agreement on an issue-by-issue basis. Each agreement will have its own appropriate time limit, requirements and conditions.

Agreements involving financial commitments by U.S. Borax will be subject to such conditions, if any, as may be agreed upon between the parties regarding the subject and effect of potential annexation of the Quartz Hill project by the Borough.

A list of issues to be discussed is attached.

Date: 3·5·86

Mayor, Ketchikan Gateway Borcugh

Date: 2-28-86

Mayor, City of Ketchikan

Date: 3-5- 86

James E Swink

Mayor, City of Saxman

Vice Chairman and President
United States Borax & Chemical
Corporation

APPROVED AS TO FORM

Russell W. Wal

Municipal Attorney

ISSUES FOR DISCUSSION

RELATING TO IMPACT OF

QUARTZ HILL MOLYBDENUM MINE DEVELOPMENT

ON KETCHIKAN AREA COMMUNITIES

COMMUNITY LIST OF DISCUSSION ISSUES

1. Monitoring
2. Cost of Living
3. Schools
4. Recreation
5. Housing and Utilities (Water & Sewer)
6. LID Guarantees
7. KPU Power
8. Traffic & Transportation
9. Law Enforcement
10. Fire Fighting/EMT
11. Airport
12. Boat Slips
13. Animal Control
14. Employer/Employee Programs
15. Social Services
16. Speculative In-Migration
17. Cumulative, Secondary, and Cyclical Impacts
18. Community Infrastructure
19. Community Maintenance and Operating Costs
20. Borax/Community "Good Guy" Program
21. Local Purchase/Local Business
22. Training/Local Hire/Native Hire
23. Hospital
24. Community Construction Scheduling

BORAX LIST OF DISCUSSION ISSUES

1. Annexation
2. Unification
3. Community Construction Scheduling
4. Application of uniform standards to situations applying to both USB and the COMMUNITY
5. Identification and due recognition of positive impacts

MEMORANDUM OF UNDERSTANDING
BETWEEN KETCHIKAN COMMUNITY AND U.S. BORAX
RELATING TO IMPACT OF
QUARTZ HILL MOLYBDENUM MINE DEVELOPMENT
ON KETCHIKAN AREA COMMUNITIES

I. WHEREAS, the City of Ketchikan, the City of Saxman and the Ketchikan Gateway Borough (hereinafter "COMMUNITY") wish to work with United States Borax & Chemical Corporation (hereinafter "USB"), acting on behalf of Pacific Coast Molybdenum Company (hereinafter "PCM"), owner of the mining claims at Quartz Hill, to alleviate impacts the development of the Quartz Hill project may have on this community; and

II. WHEREAS, the U.S. Forest Service, as part of its requirement to address the socioeconomic impacts for the Environmental Impact Statement ("EIS") process, has recommended "that U.S. Borax and the Ketchikan community governments enter into a Memorandum of Understanding which is mutually acceptable and provides for mitigation of adverse socioeconomic consequences"; and

III. WHEREAS, Quartz Hill lies beyond COMMUNITY boundaries or any other local taxing jurisdiction; and

IV. WHEREAS, USB agrees that as a good corporate citizen, the developer of Quartz Hill should be responsive to the request by COMMUNITY and the recommendation of the U.S. Forest Service to assist in good faith in efforts to solve the socioeconomic impacts on the community; and

V. WHEREAS, both USB and COMMUNITY concur that the parties should commit to a good faith effort to negotiate an agreement as recommended by the U.S. Forest Service; and

VI. WHEREAS, USB and COMMUNITY desire to enter into this "agreement in principle" to be known as the Memorandum of Understanding (hereinafter known as "MOU") that establishes a framework for agreement on identification of impacts and measures on a case-by-case basis, and to alleviate the social and economic consequences of the planned

development, extraction and processing of the Quartz Hill molybdenum deposit.

NOW, THEREFORE, be it remembered:

1. USB and the COMMUNITY acknowledge that there will be certain impacts, both favorable and unfavorable, on the COMMUNITY caused by the construction and operations of the Quartz Hill project.

2. Solutions to adverse socioeconomic impacts may involve action by COMMUNITY, USB, the State of Alaska or the U.S. Forest Service, or any combination thereof. It is understood that the resultant solutions should be sensitive to and attempt to minimize negative impacts on government service levels, the future tax burden on the residents of the community and the economic well-being of the Quartz Hill project.

3. USB and COMMUNITY hereby enter into this agreement in principle, known as the MOU, that establishes the process by which the parties hereto will work toward entering into a Community-Quartz Hill Agreement (hereinafter referred to as "CQHA") relating to workable and mutually acceptable solutions for the unfavorable impacts and for enhancement of the favorable impacts of the Quartz Hill project.

4. The parties hereto intend that the principle of such solutions shall be that each party agrees to incur its fair share of responsibility and to recognize the value of positive impacts in addressing the negative impacts.

5. This MOU shall become effective on the date it is signed by all of the parties hereto and shall remain in effect until superseded by the CQHA or until five years after the start of operations of the mine, whichever occurs first.

6. This MOU is a general statement of the understandings and intents of USB and COMMUNITY, with regard to the means by which USB and COMMUNITY will work together to agree as to how to reduce the negative impacts and accentuate the positive impacts of USB's development of the Quartz Hill molybdenum deposit on the COMMUNITY.

7. USB and COMMUNITY agree that the CQHA will supersede all previous agreements between the parties.

8. USB and COMMUNITY have previously agreed on a procedure document for the step-by-step process to continue discussions for resolution of the potential socioeconomic impacts of the Quartz Hill project. This document is titled, "Agreed Procedure for Ketchikan Community/U.S. Borax Discussions" and is included in its entirety as a part of this agreement and is attached hereto.

9. USB and COMMUNITY agree that the list of issues displayed in the Agreed Procedure Document represents the parties' present understanding of the major issues to be discusssed for definition and resolution and further agree that items therein can be deleted, added or amended by mutual agreement.

10. The parties agree that reasonable efforts shall be made to provide for assimilation of USB's employees and families into the community.

11. Finally, USB and COMMUNITY agree to the following provisions to lessen and resolve the unfavorable social and economic consequences of USB's development, extraction and processing of the Quartz Hill molybdenum deposit and their intent to work in good faith to identify and agree upon workable and mutually acceptable solutions for mitigation of the unfavorable impacts:

A. To provide the means by which USB and COMMUNITY will continue to work together to reduce the negative impacts and accentuate the positive impacts of USB's develcpment of the Quartz Hill molybdenum deposit on this community, USB and COMMUNITY hereby commit to include provisions in the CQHA whereby each party will designate one or more representatives and establish procedures to meet as often as is reasonably necessary but

not less frequently than annually for informational and problem-solving purposes.

B. USB commits to provide COMMUNITY with a minimum of one (1) year advance notice prior to beginning mill and mine plant construction to allow reasonable forecasting of COMMUNITY capital and program needs; provided, however, that the term "mill and mine plant construction" shall not include facility design engineering, related survey work, site clearing, grubbing and grading, road access development, construction of yards and other incidental on-site project work.

C. USB agrees to provide COMMUNITY with reasonable advance notice of planned shutdowns which will last six (6) months or longer or of changes of fifty (50) percent or greater in "nameplate" capacity of the mill or mine.

D. USB and COMMUNITY agree to establish and maintain a mutually agreed comprehensive monitoring program, to begin with the effective date of this MOU and to be maintained through at least the end of the first five (5) years of mine operation after construction, to provide routine and regular reporting of certain specified indices reflecting project development and changes. Examples of information that would prove useful may include, but are not hereby limited to, timetables of worker arrivals and departures, timetables of any and all significant changes in scope or type of operations and demographic profiles of workers.

E. USB hereby agrees to convey the requirements of this MOU and the CQHA to USB's successors and assigns, and to notify COMMUNITY regarding changes of ownership interests in the Quartz Hill molybdenum deposit.

F. USB and COMMUNITY recognize that mediation may be an effective means to resolve issues which cannot otherwise be resolved by the parties to this MOU, and shall, therefore, include in the CQHA a provision for referral of such matters to mediation on a voluntary, non-binding basis.

G. USB agrees to employ a community liaison officer from the effective date of this MOU through at least the last day of the first five (5) years of operation following construction, said individual to have specific, though not necessarily exclusive responsibilities to work with COMMUNITY, individual persons, firms and agencies to ensure that accurate and timely information about the project is readily available to the general public, that the public's questions are timely answered and that rumors are "controlled"; and said individual to be a member of the U.S. Borax local staff upon notification of start of construction.

IN WITNESS WHEREOF, the Ketchikan Gateway Borough, the City of Ketchikan, the City of Saxman and the United States Borax & Chemical Corporation, upon behalf of Pacific Coast Molybdenum Company, have all entered into this Memorandum of Understanding as evidence of their intent to deal with the mitigation impacts of the Quartz Hill project in good faith.

Ketchikan Gateway Borough

BY Ernest J. Hansen
Vice- Mayor

DATE 9-25-86

City of Ketchikan

BY_______________________
Mayor

DATE 9-24-86

City of Saxman

BY James C. Sevind
Mayor

DATE 9/26/86

United States Borax & Chemical Corporation
on behalf of
Pacific Coast Molybdenum Company

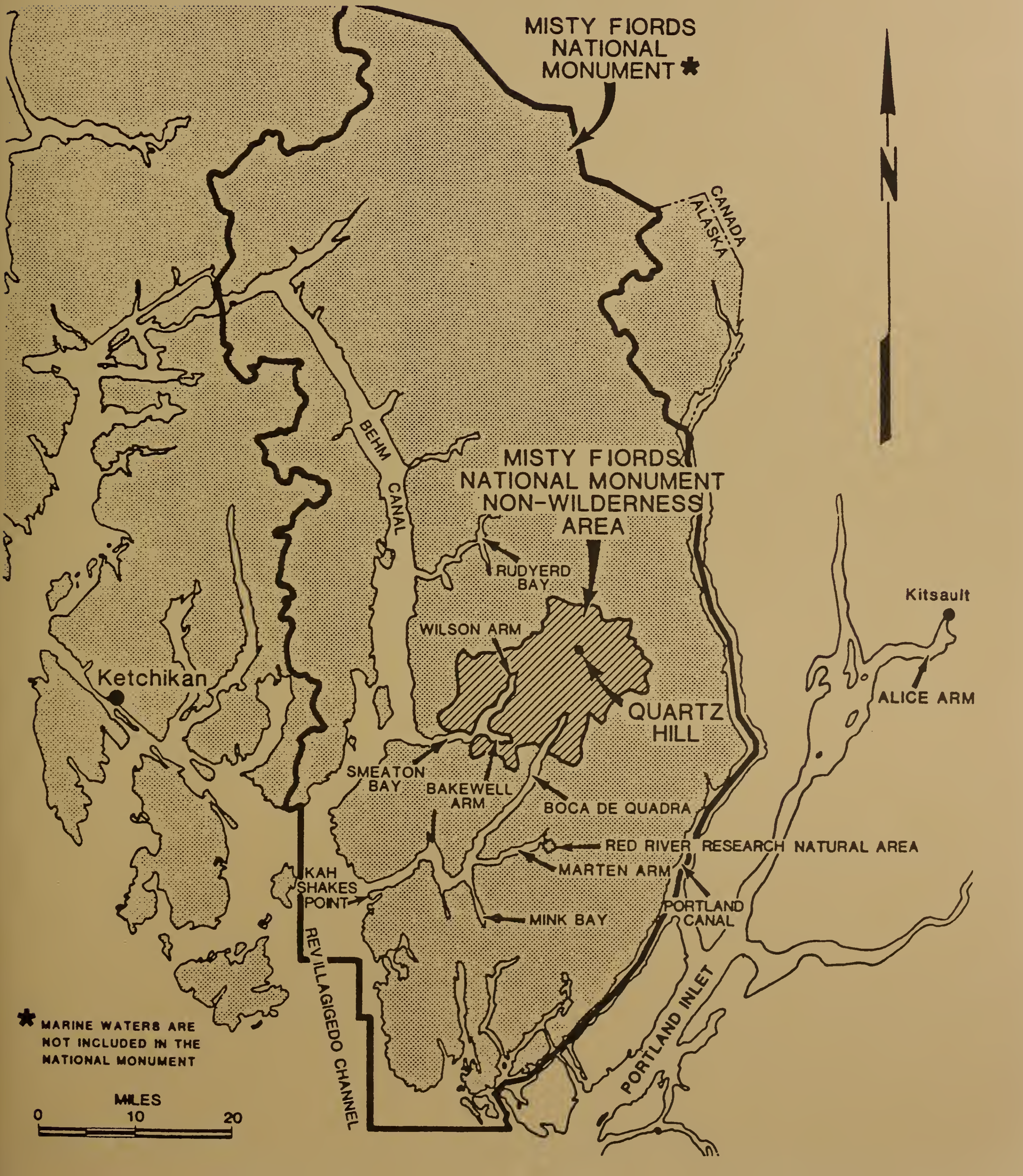
BY_______________________
Vice Chairman and President

DATE 10/10/86

Approved as to Form in accordance with Ketchikan Gateway Borough Code Section 5.50.030

Russell W. Wall
Municipal Attorney

APPENDIX J
STATE & NATIONAL ECONOMICS



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STATE AND NATIONAL ECONOMICS

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0942K

1.0 STATE BUDGET AND POPULATION CHANGES IN ALASKA FISCAL YEARS 1961-1983

Between fiscal year (FY) 1961 and FY 1983, Alaska's population grew at a compound annual rate of 3.1 percent, while real (constant dollar) expenditures expanded at the compound annual rate of 15.1 percent (see Table J-1).

Figure J-1 graphically displays the relationship between population growth and expenditure growth. While the two showed similar trends from 1961 through 1979, the large increase in the Alaska state budget in 1980 can be attributed to a substantial increase in oil revenue rather than to an increased population.

TABLE J-1

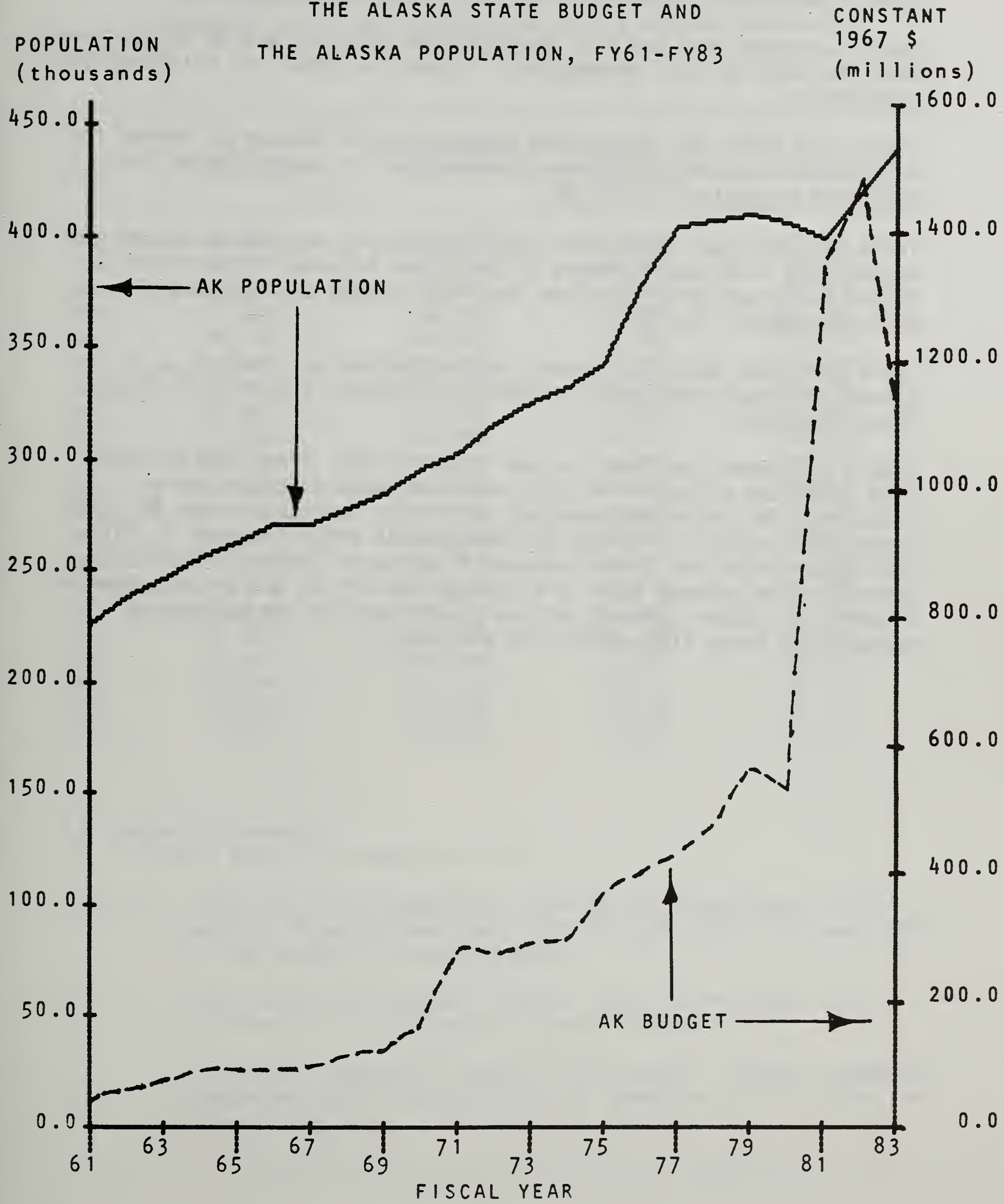
ALASKA STATE BUDGET AND POPULATION
FY61-FY83

Fiscal Year	Alaska Population (000)	Budget (1976 $) Millions	Per Capita Budget ($)	Change in Population (000)	Change in Budget (million $)
61	226	49.9	221	-	-
62	238	56.3	237	12	6.4
63	246	71.0	288	8	14.7
64	256	88.9	347	10	17.9
65	263	84.2	320	7	-4.7
66	271	91.4	338	8	7.2
67	271	95.8	354	0	4.5
68	278	113.1	407	7	17.3
69	285	124.5	437	7	11.4
70	296	161.1	544	11	36.6
71	302	278.7	923	6	117.6
72	316	271.4	859	14	-7.3
73	326	292.7	898	10	21.3
74	332	299.2	902	6	6.5
75	343	365.8	1067	11	66.6
76	379	399.0	1052	36	33.2
77	405	427.3	1055	26	28.3
78	408	475.0	1165	3	47.7
79	411	565.9	1376	3	90.9
80	406	536.1	1320	-5	-29.8
81	400	1337.0	3343	-6	800.9
82	420	1482.2	3529	20	145.2
83	441	1088.9	2469	21	-393.3

Sources: Alaska Legislative Finance Division 1982.
Alaska Department of Labor 1982.

FIGURE J-1

THE ALASKA STATE BUDGET AND THE ALASKA POPULATION, FY61-FY83



Prepared by ERICKSON & ASSOCIATES 1983

Sources: Alaska Department of Labor 1983, and Legislative Finance Division 1982

2.0 MOLYBDENUM PRODUCTION AND PRICE TRENDS

Tables J-2 through J-4 and Figures J-2 through J-9 provide background data on molybdenum production, prices, and world demand.

Table J-2 shows that the U.S. exports have been increasing to represent more than half of U.S. production. Figure J-2 shows the relationships graphically.

Figure J-3 shows the fluctuating nature of U.S. industrial demand for molybdenum, including the dramatic reduction in demand during the recession beginning in 1979-80.

Table J-3 indicates that since 1962, industrial molybdenum demand has represented a decreasing share of the Gross National Product (GNP). Figure J-4 graphically displays the relationship of U.S. demand measured against the GNP.

Table J-4 shows that U.S. demand and production has dropped as a percent of total free world production. Figures J-5 and J-8 display these concepts.

Figure J-9 shows the trend in real dealer prices from 1915 through 1983, with the exception of 1937 and 1938, when no prices were reported. The price has remained relatively constant in the $4 to $6 range (1982 dollars), except for the unusual price increase in 1979. The dealer price has since returned to historic levels. About 20 percent of molybdenum sales are through dealers at the prices shown in Figure J-9. Other contract prices govern most of the molybdenum market, but those figures are not available.

0942K

TABLE J-2

MOLYBDENUM PRODUCTION, U.S. EXPORTS, AND U.S. DEMAND
(Thousands of lbs of contained Mo in ore and concentrates)
1962-1982

YEAR	U.S. PRODUCTION	FREE WORLD PRODUCTION	U.S. EXPORTS	U.S. DEMAND 1/
1962	51,244	59,300	15,555	36,162
1963	65,011	75,000	26,545	42,455
1964	65,605	78,000	24,940	46,377
1965	77,373	98,400	27,191	54,460
1966	90,532	124,988	29,768	61,870
1967	90,097	126,273	30,000	54,848
1968	93,447	128,071	29,006	56,199
1969	99,807	142,639	57,575	50,274
1970	111,352	163,648	55,737	50,274
1971	109,592	149,854	46,284	40,807
1972	112,138	152,708	45,362	51,598
1973	115,859	161,388	73,958	73,449
1974	112,011	166,264	78,660	71,612
1975	105,980	156,713	62,611	55,302
1976	113,233	171,274	62,474	59,949
1977	122,408	184,695	65,666	61,350
1978	131,843	198,428	69,150	67,724
1979	143,967	202,193	72,243	73,682
1980	150,686	211,190	68,217	60,754
1981	139,900	195,070	52,436	61,103
1982 2/	75,000	157,000	45,000	33,000

1/ Industrial demand.
2/ Estimates based on 9 months of data.

Sources: 1962-1976, U.S. Production, Free Worlds Production, and U.S. Exports, Minerals Yearbook, 1962 through 1976, U.S. Department of the Interior, Bureau of Mines.

1962-1976, U.S. Demand: Mineral Facts and Problems, U.S. Department of the Interior, Bureau of Mines.

1977-1982, Production, Exports, and Demand: Mineral Commodity Summaries, 1977 through 1982, U.S. Department of the Interior, Bureau of Mines.

0942K

FIGURE J-2

Source: See Table J-2

1982 is estimated on the basis of 9 months of data.

Prepared by ERICKSON & ASSOCIATES, November 1983.

FIGURE J-3

Source: See Table J-3

1982 is estimated on the basis of 9 months of data.

Prepared by ERICKSON & ASSOCIATES, November 1983.

TABLE J-3

MOLYBDENUM DEMAND MEASURED AGAINST REAL GNP
1962-1982

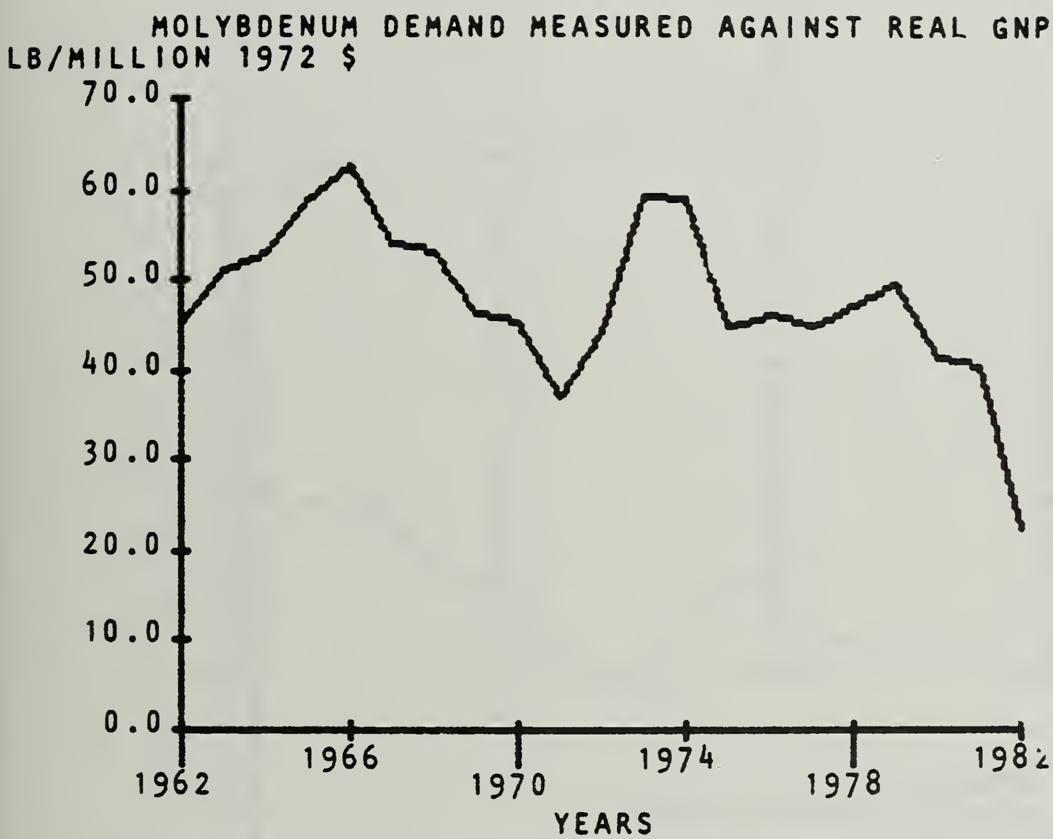
YEAR	GNP (BILLIONS OF 1972 $)	U.S. INDUSTRIAL DEMAND (THOUSANDS OF LBS)	LBS MOLYBDENUM PER MILLION $ OF GNP
1962	796.9	36,162	45.38
1963	828.8	42,455	51.22
1964	874.1	46,377	53.06
1965	929.3	54,460	58.69
1966	989.9	61,870	62.50
1967	1,015.6	54,848	54.01
1968	1,062.9	56,199	52.87
1969	1,091.5	50,274	46.06
1970	1,085.6	49,166	45.29
1971	1,107.5	40,807	36.85
1972	1,171.1	51,598	44.06
1973	1,235.0	73,449	59.47
1974	1,214.0	71,612	58.99
1975	1,231.6	55,302	44.90
1976	1,298.0	59,949	46.19
1977	1,369.7	61,350	44.79
1978	1,438.6	67,724	47.08
1979	1,479.4	73,682	49.81
1980	1,475.0	60,754	41.19
1981	1,513.8	61,103	40.36
1982 1/	1,485.4	33,000	22.22

1/ Estimates based on 9 months of data.

Sources: GNP: Statistical Abstracts of the United States, U.S. Department of Commerce, Bureau of the Census, and Historical Statistics of the United States, 1970-1982, U.S. Department of Commerce, Bureau of the Census. Demand: Mineral Facts and Problems, U.S. Department of the Interior, Bureau of Mines, 1962-1976.

0942K

FIGURE J-4



Source: See Table J-3

1982 is estimated on the basis of 9 months of data.

Prepared by ERICKSON & ASSOCIATES, November 1983.

TABLE J-4

MOLYBDENUM PRODUCTION AND INFORMATION
EXPRESSED IN PERCENTAGES
1962-1982

YEAR	U.S. PRODUCTION AS A PERCENT OF FREE WORLD PRODUCTION	U.S. EXPORTS AS A PERCENT OF U.S. PRODUCTION	U.S. EXPORTS AS A PERCENT OF FREE WORLD PRODUCTION	U.S. DEMAND AS A PERCENT OF FREE WORLD PRODUCTION 1/
1962	86	30	26	61
1963	87	41	35	57
1964	84	38	32	59
1965	79	35	28	55
1966	72	33	24	50
1967	71	33	24	43
1968	73	31	23	44
1969	70	58	40	35
1970	68	50	34	30
1971	73	42	31	27
1972	73	40	30	34
1973	72	64	46	46
1974	67	70	47	43
1975	68	59	40	35
1976	66	55	36	35
1977	66	54	36	33
1978	66	52	35	34
1979	71	50	36	36
1980	71	45	32	29
1981	72	37	27	31
1982 2/	48	60	29	21

1/ Industrial demand.
2/ Estimates based on 9 months of data.

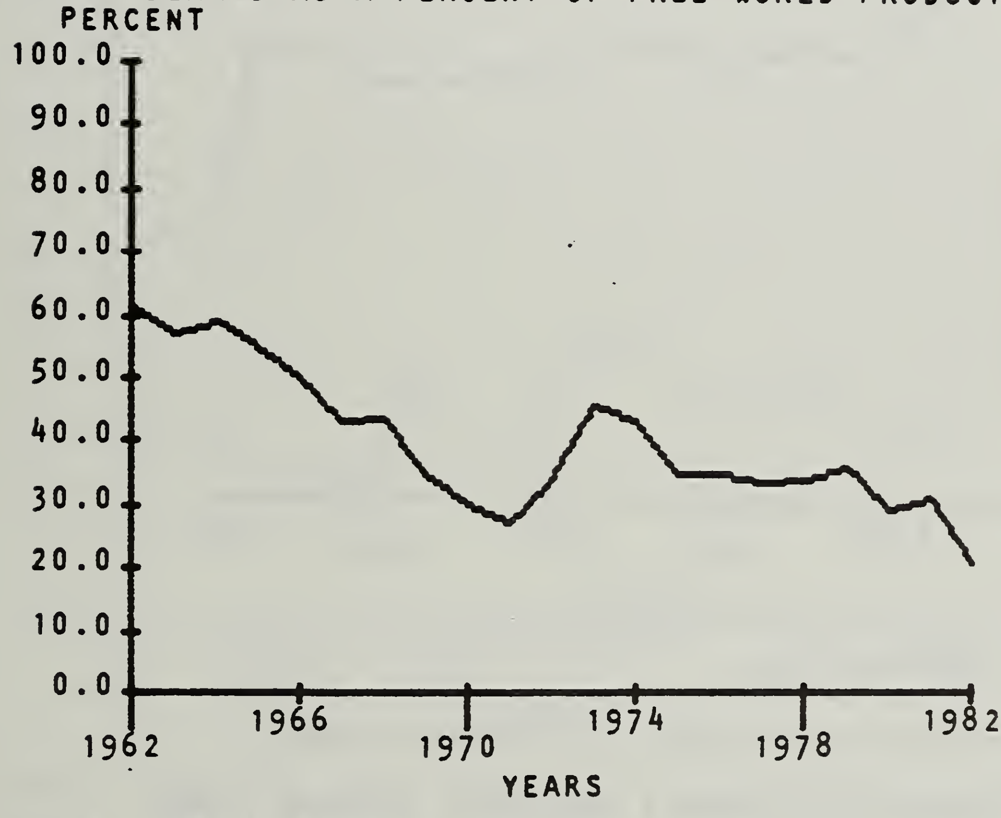
Source: See Table J-2.

0942K

FIGURE J-5

MOLYBDENUM

U.S. DEMAND AS A PERCENT OF FREE WORLD PRODUCTION

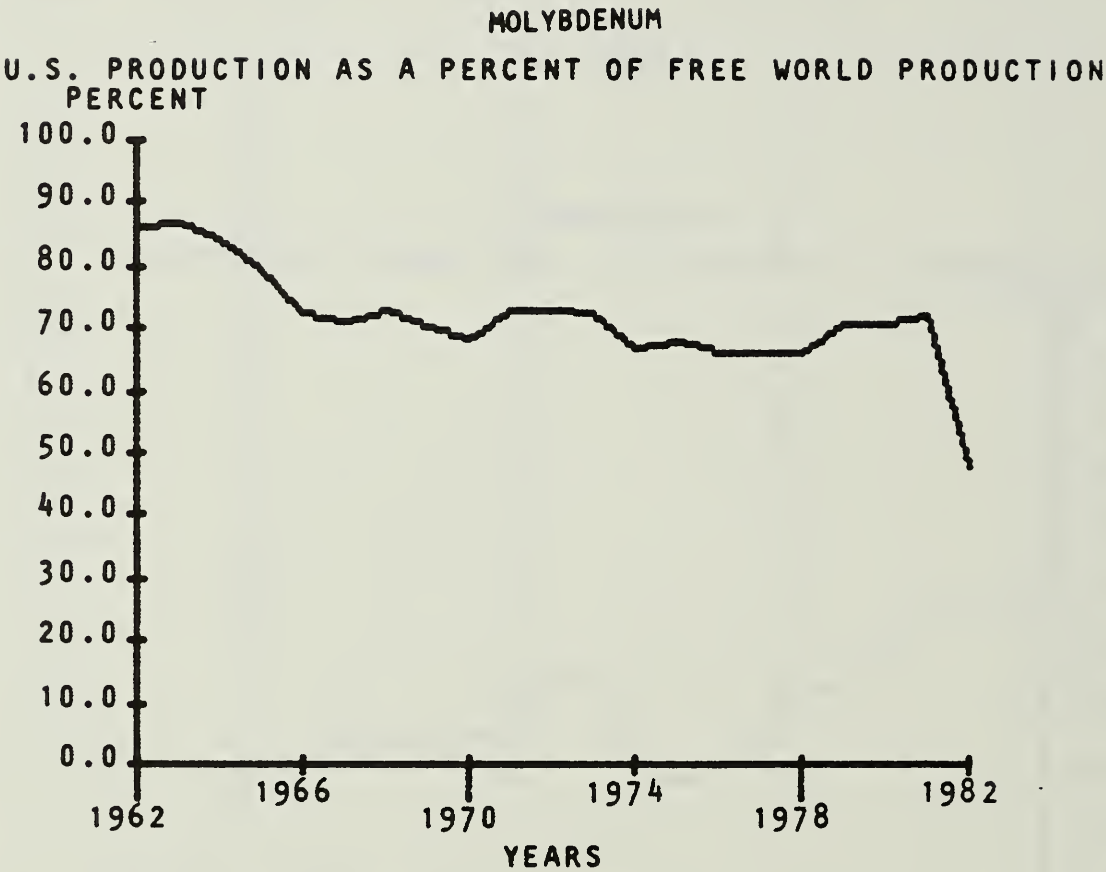


Source: See Table J-4

1982 is estimated on the basis of 9 months of data.

Prepared by ERICKSON & ASSOCIATES, November 1983.

FIGURE J-6



Source: See Table J-4

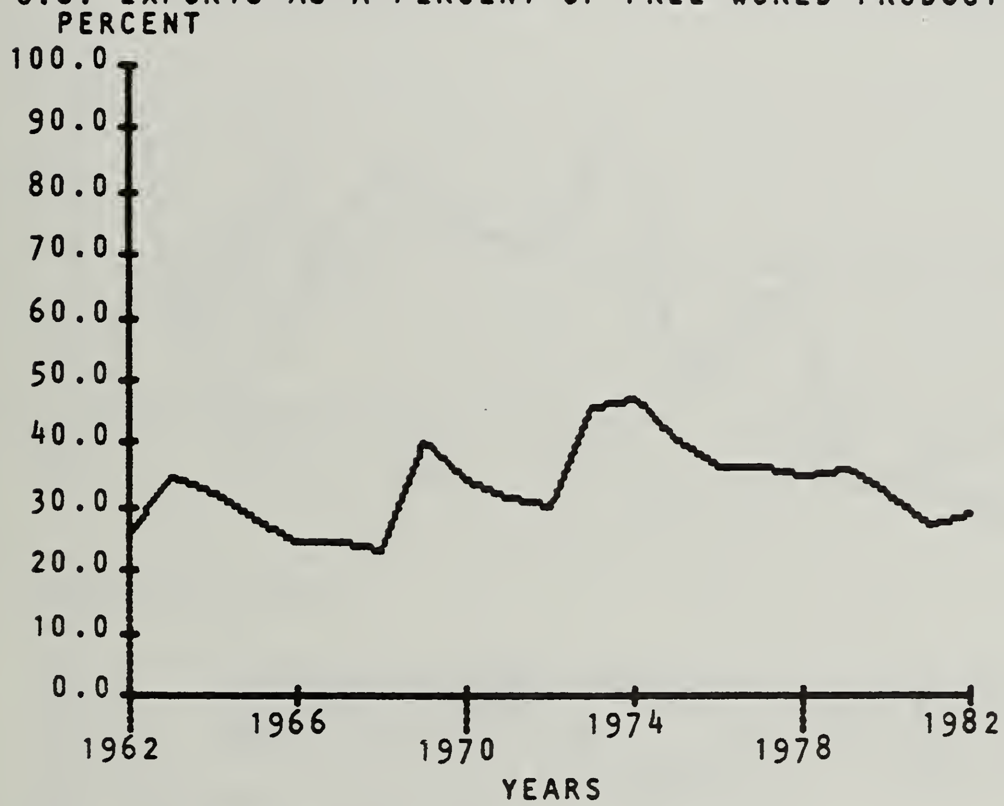
1982 is estimated on the basis of 9 months of data.

Prepared by ERICKSON & ASSOCIATES, November 1983.

FIGURE J-7

MOLYBDENUM

U.S. EXPORTS AS A PERCENT OF FREE WORLD PRODUCTION



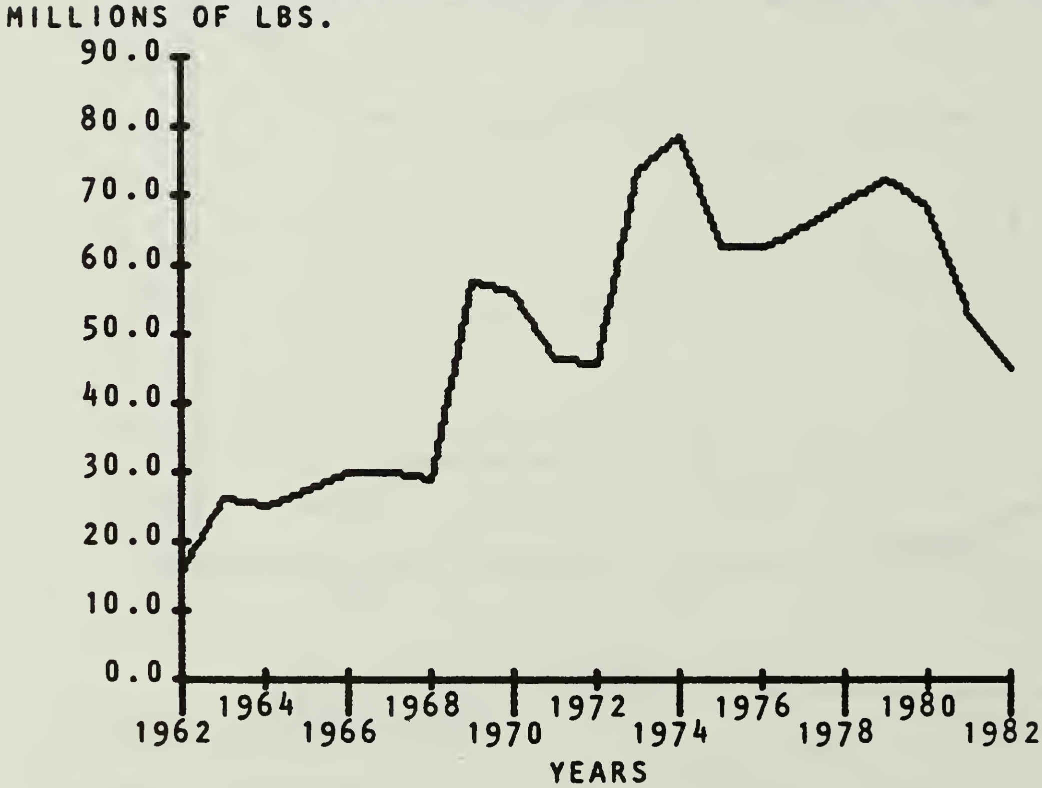
Source: See Table J-4

1982 is estimated on the basis of 9 months of data.

Prepared by ERICKSON & ASSOCIATES, November 1983.

FIGURE J-8

U.S. MOLYBDENUM EXPORTS OF ORE AND CONCENTRATES



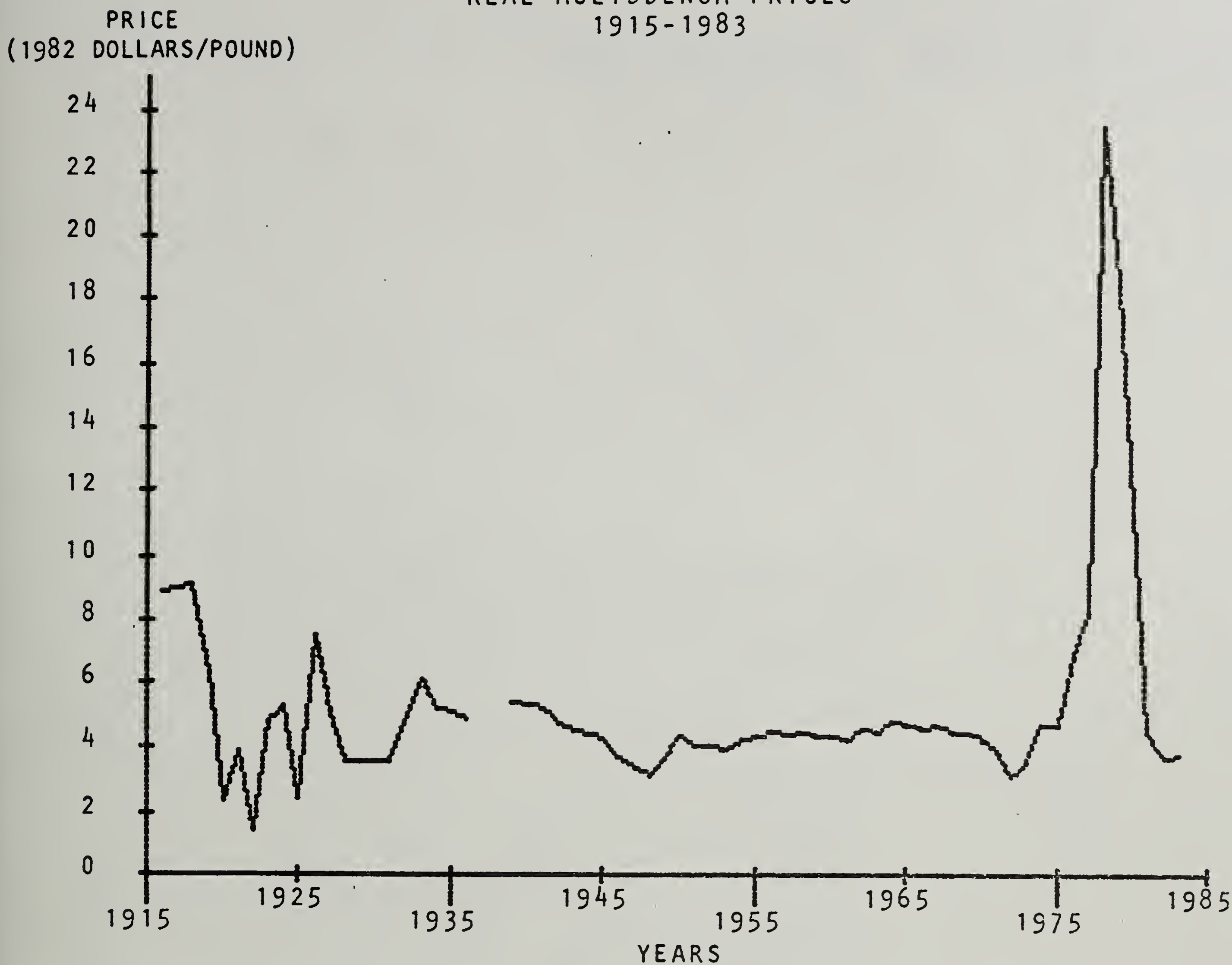
Source: See Table J-2

1982 is estimated on the basis of 9 months of data.

Prepared by ERICKSON & ASSOCIATES, November 1983.

FIGURE J-9

REAL MOLYBDENUM PRICES
1915-1983



SOURCES AND NOTES:

1915 to 1931 prices - Minerals Yearbook, U.S. Department of the Interior, Bureau of Mines.
1932 to 1981 prices - Mineral Resources of the United States, U.S. Department of the Interior, Bureau of Mines, U.S. Geological Survey, and U.S. Department of Commerce.
1982, 1983 prices - Metals Week, McGraw-Hill, Inc.

Prices from 1915 to 1920 are for "contained Mo in ore and concentrates;" prices from 1921 to 1924 are for "concentrated ore imports;" and from 1925 to 1936 prices are for "contained Mo in ore and concentrates." No U.S. or import prices were reported for 1937 and 1938. Prices from 1939 to 1981 are for "Molybdic Oxide;" and 1982 and 1983 prices are for "dealer quality Molybdic Oxide."

All prices were adjusted to March 1982 dollars using the Wholesale Price Index for for 1915-1925, and using the GNP Deflator for 1926-1983.

Prepared by ERICKSON & ASSOCIATES, October 1983

APPENDIX K
CULTURAL RESOURCES

APPENDIX K

CULTURAL RESOURCES

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APPENDIX K - CULTURAL RESOURCES

I. SUMMARY

Appendix K presents data on the geologic and ethnographic history of the area and summarizes the results of previous work in the study area. Based on this information predictions were made about the types and locations of cultural resources. Types of cultural resources that may be expected include early prehistoric sites, winter campsites, hunting and trapping sites, fish weirs and fish camps, and hand logging sites. The project area is divided into environmental/topographic zones of differential probability for containing cultural resources. High probability zones include stream mouths, floodplains, the intertidal zone, other coastal zones of less than 60 percent slope, and late-Pleistocene to early-Holocene marine deposits. Moderate probability zones include portions of the coast of greater than 60 percent slope, inland stream crossings and river valleys, and forested valley sideslopes of less than 60 percent slope. Low probability zones include tideflats, inland hillsides of greater than 60 percent slope, and muskegs. Project impacts are evaluated against these probabilities as well as the magnitude, extent, and duration of the impacts upon cultural resources. A conservative scenario is assumed in rating the potential impacts because the exact locations of all cultural resources within the project area have not yet been identified.

II. DATA SOURCES

The geologic and climatic history of the project area has some influence on where cultural resources may be located. During the last Pleistocene glaciation, the mainland was covered with a thick ice sheet which would have obliterated any evidence of prior human occupations and rendered the mainland uninhabitable until approximately 10,000 years ago when the ice retreated (Heusser 1960, p. 183). Fladmark (1979) postulates that man occupied biotic refugia on the outer coast during the peak glaciation and populated the newly deglaciated portions of the mainland coast as they became habitable. Maximum post-glacial sea levels relative to the land would have obliterated evidence of human occupations of the coast dating prior to approximately 9000 years ago (Fladmark 1979, p. 62). By that time, however, landforms were rising relative to sea level through isostatic rebound, and beaches dating to 9000 years ago, with any evidence of human coastal occupation, may today be well above sea level. The amount of isostatic rebound varies throughout southeast Alaska and no specific data are available for the project area, but evidence from the Ketchikan region suggests that early Holocene marine sediments may be found at elevations of 80 to 500 ft above present sea level (Twenhofel 1952, p. 526).

Significant isostatic rebound in the area appears to have ceased by at least 6000 years ago. Minor rises in sea level amounting to 5 to 6 ft occurred during the Hypsithermal, a period of maximum glacial retreat which dates to 8000 to 3500 years ago in the Alexander Archipelago (Heusser 1960, pp. 184, 189). Sea levels have fallen since then, leaving wave-cut benches at or slightly above the present high tide line (Buddington and Chapin 1929; Heusser 1960, pp. 21-22). Human coastal occupations dating to the Hypsithermal may be located just above these abandoned benches.

There have been several Holocene advances of alpine glaciers in southeast Alaska. The most recent episode culminated as recently as 100 to 200 years ago (Heusser 1960, p. 19; Pewe 1975, pp. 32-34). Its effects on the project area are unknown but, if it did occur here, the ice would have scoured earlier deposits from the high mountain valleys, removing with them any traces of earlier human occupations.

Finally, some river deltas in the Alexander Archipelago have been building throughout the Holocene. There is archeological evidence that sites once located at river mouths could today be found in estuarine deposits a kilometer or more inland (de Laguna 1960, p. 32; Roberts 1982, p. 3).

Information on ethnographic and historic land use also helps to predict where cultural resources may be located. Historically, two Native peoples, the Tsetsaut or Wetalth Athabaskans and the Sanyakwan or Cape Fox Tlingit, are known to have inhabited the project area (Campbell 1980, 1981; Duff 1981; Emmons 1911, p. 22; Goldschmidt and Haas 1946, pp. 134-144; Hodge 1913, p. 486). Both peoples are thought to have some antiquity in the area, but enthnographic sources provide no firm data on how long either had been living in the general vicinity at the time of European contact.

The Tsetsaut were an inland-oriented people who subsisted primarily on land mammals and moved frequently throughout the year. In the spring and summer they descended to the coastal fish streams where they took salmon and eulachon. In the late summer and fall they dispersed to trap marmots, their most important food source, on the steep mountain slopes. In the fall, the men hunted mountain goats. Individual families dispersed to mountain valleys in the winter. Each man worked one valley at a time, hunting and trapping. The Tsetsaut apparently had no permanent villages, but returned repeatedly to favored campsites. Their dwellings were single or double lean-tos of poles covered with bark, erected at the bases of large trees. The poles were disassembled and stored for later use at the site when a family moved camp (Campbell 1981, p. 11-12; Duff 1981, p. 456).

The Sanyakwan, by contrast, lived on the coast. They resided in several permanent coastal villages near, but not in, the study area in the early historic period. Seasonally, they occupied fish camps on

important salmon streams. Their hunting, trapping, and berry gathering were also concentrated near the coast (Campbell 1980, p. 7; Goldschmidt and Haas 1946, pp. 134-144 and Chart 12). Their permanent dwellings were substantial multifamily structures, but only small cabins or smokehouses were erected at the fish camps. Lean-tos and other ephemeral structures were used on hunting and trapping trips.

The two peoples appear to have had some territorial overlap and generally friendly relations prior to 1835 (Campbell 1981, pp. 4, 6). Some time later a blood feud began between them which caused the Tsetsaut to move to the Portland Canal area and led to their near extinction by 1885 (Campbell 1981, pp. 6-9; Duff 1981, pp. 455-456; Hodge 1913, p. 486). The Sanyakwan continued to fish, hunt, and trap in the Smeaton Bay and Boca de Quadra areas into the twentieth century (Goldschmidt and Haas 1946, pp. 134-136).

Information on EuroAmerican use of the project area is confined to the twentieth century. Intermittent hunting and trapping have occurred here since early in this century. Hand logging of the shores of Smeaton Bay had begun by the mid-1920s, if not earlier, and persisted until at least 1947 (Jackson 1974, pp. 34, 43, 56, 191). The whole region has been prospected for various minerals since the late 1890s, but no significant finds were reported in the project area prior to recent times (Brooks 1902, plate II, p. 108; Wright and Wright 1908, p. 185; Wolff and Heiner 1971).

While it appears that there is moderate to high potential for cultural resources in some parts of the project area, the area is poorly known archeologically. The earliest report of cultural remains comes from George Vancouver, who discovered a Native burial box and the remains of a few "huts" in Smeaton Bay in 1793, possibly near the head of Wilson Arm (Ackerman and Gallison 1981, p. 9). An unconfirmed burial site at the confluence of the Wilson and Blossom rivers, reported by the Sealaska Corporation, may refer to this same site (ERTEC 1982, p. II-13). Goldschmidt and Haas, who interviewed informants to document Native traditional land use, reported two smokehouses at the head of Smeaton Bay (Wilson Arm) and one near the head of Boca de Quadra, apparently at the mouth of Aronitz Creek (Goldschmidt and Haas 1946, p. 136 and Chart 12). The smokehouses reported at the head of Wilson Arm may correspond to the site of six smokehouses at the confluence of the Wilson and Blossom rivers reported to Ackerman and Gallison in 1980. None of these locations have been confirmed archeologically.

Two archeological surveys have been conducted specifically for this project. Ackerman and Gallison (1981) conducted reconnaissance level surveys by boat and on foot along the shores of Wilson Arm, Bakewell Arm, upper Boca de Quadra, and the lower Wilson and Blossom rivers, and by helicopter over the mountainous interior between Wilson Arm and Boca de Quadra. They located 21 sites in all, 5 of them modern and in current use, 11 modern and abandoned, and 5 of historic age which they

felt warrant shovel testing for earlier components. All of the latter were in the river estuary and coastal zone. A second survey, consisting of systematic shovel testing of the access road corridor from Wilson Arm to Quartz Hill and of the proposed locations of six rock quarries, a barge offloading facility, and a boat landing and temporary floating camp, was conducted by ERTEC (1982). ERTEC archeologists made every effort to shovel test inland as well as coastal areas, and areas of moderate to low cultural resource potential as well as areas of high potential. They identified no new cultural resources, but did test two historic sites and one modern abandoned site previously identified by Ackerman and Gallison. No earlier components were discovered at these sites. The ERTEC team concluded that the two historic sites are unlikely to meet the criteria of significance which would make them eligible for inclusion on the National Register of Historic Places, but apparently did not go through a formal determination process. They concluded that the modern site is insignificant and does not qualify for the National Register of Historic Places. Sites identified or reported in the project area to date are summarized in Appendix Table K-1. The locations of the potentially significant sites, where known, are identified in Appendix Figure K-1.

III. METHODOLOGY AND ASSUMPTIONS

Locations of Cultural Resources

Based upon the data presented above, some predictions can be made about the types and locations of cultural resources which could potentially be found within the project area (after ERTEC 1982, pp. II-32, II-33).

Early Prehistoric Sites:

No sites predating 9000 to 10,000 years ago are expected due to glacial activity. Early Holocene marine and estuarine deposits, which could contain cultural remains dating to 6000 to 9000 years ago, might occur up to 500 ft above present sea level or a kilometer or more inland. Mid-Holocene coastal sites would be expected to occur slightly above the present high-tide line. Inland sites older than 100 to 200 years are not expected to be preserved in mountain valleys subject to the most recent alpine glaciation.

Winter Campsites:

These may occur in inland river valleys occupied by the Tsetsaut. The sites may be stratified due to repeated use.

Hunting and Trapping Sites:

The Tsetsaut trapped marmots on steep mountain slopes and hunted mountain goat in the alpine zone. The Sanyakwan Tlingit did some

APPENDIX TABLE K-1

PREVIOUSLY RECORDED SITES IN PROJECT VICINITY

Site Number	Site Type	Historical Significance	Source
KET 038	reported burial box discovered by Capt. G. Vancouver in 1793; possibly associated with fish camp	potentially significant if found	Alaska Heritage Resources Survey
---	unconfirmed burial site, possibly same as KET 038	potentially significant if found	ERTEC (1982) (from Sealaska Corporation)
Ackerman No. 1	Forest Service cabin	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 2	U.S. Borax fuel cache	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 3	U.S. Borax mining camp	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 4	modern abandoned camp	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 5	historic campsite	potentially significant, though ERTEC considers it unlikely	Ackerman and Gallison 1981
Ackerman No. 6	historic cabin ruin	potentially significant, though ERTEC considers it unlikely	Ackerman and Gallison 1981
Ackerman No. 7	modern trap site, abandoned	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 8	modern abandoned camp	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 9	oval depression	potentially significant (origin unknown)	Ackerman and Gallison 1981
Ackerman No. 10	dock piling; trail	piling not significant (recent), but trail may have subsurface resources along it	Ackerman and Gallison 1981

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APPENDIX TABLE K-1 (Continued)

Site Number	Site Type	Historical Significance	Source
Ackerman No. 11	cabin ruin	probably not significant unless older than 50 yrs	Ackerman and Gallison 1981
Ackerman No. 12	modern cabin ruin	probably not significant (20 to 30 years old)	Ackerman and Gallison 1981
Ackerman No. 13	modern cabin or tent floor	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 14	historic piling; cabin foundation	potentially significant	Ackerman and Gallison 1981
Ackerman No. 15	scarred hemlock trees	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 16	modern weather station	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 17	modern cabin	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 18	modern campsite	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 19	U.S. Borax fuel cache; reported site of smokehouse	potentially significant if smokehouse found	Ackerman and Gallison 1981
Ackerman No. 20	modern tent frame	not significant (recent)	Ackerman and Gallison 1981
Ackerman No. 21	modern campsite	not significant (recent)	Ackerman and Gallison 1981
---	reported smokehouse	potentially significant if found (see Ackerman No. 19)	Goldschmidt and Haas 1946
---	two reported smokehouses	potentially significant if found (could be at or near site KET 038)	Goldschmidt and Haas 1946
---	six reported smokehouses	potentially significant if found (could be same as above site	Ackerman and Gallison 1981

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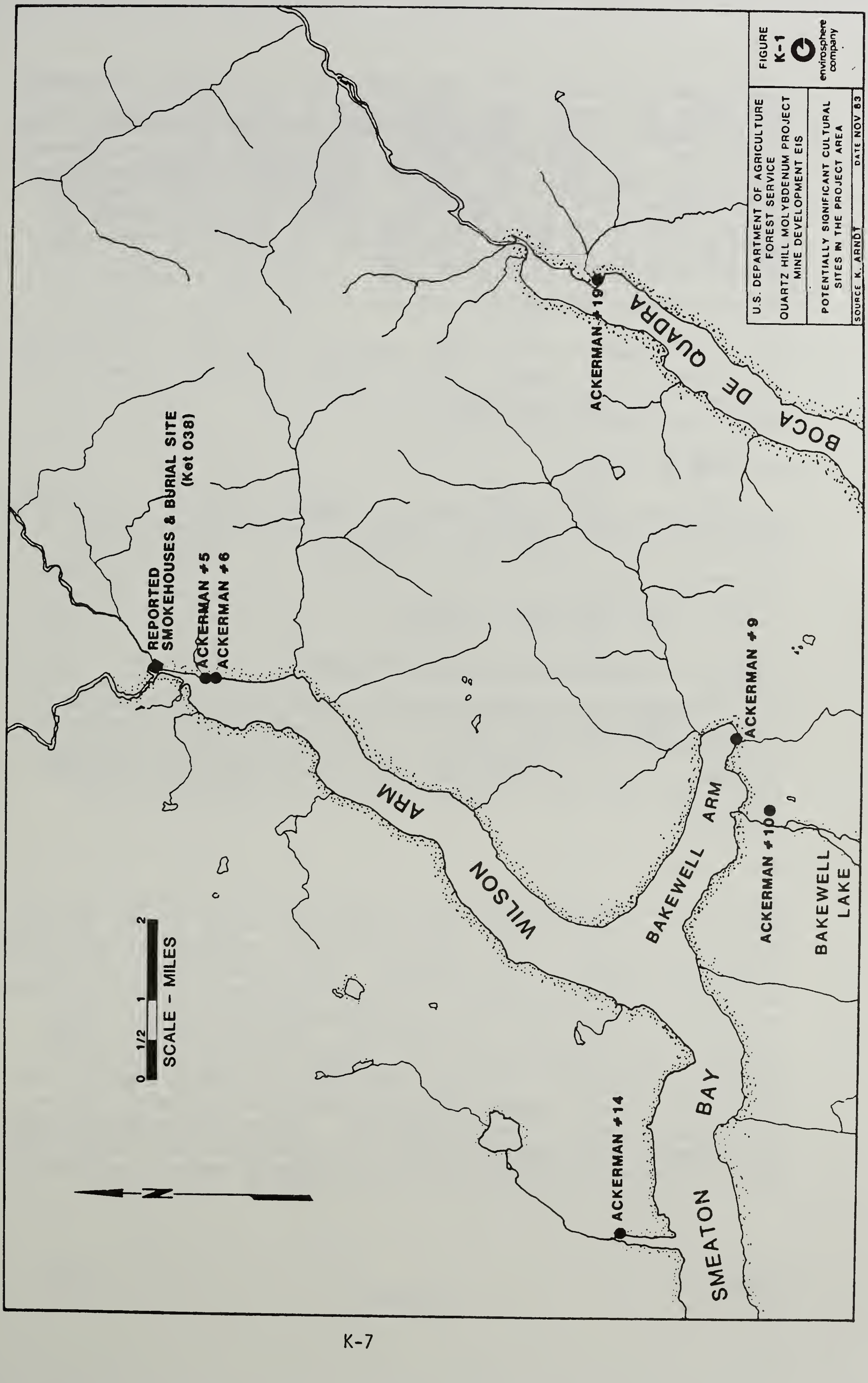

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS
POTENTIALLY SIGNIFICANT CULTURAL
SITES IN THE PROJECT AREA
SOURCE K. ARNDT
DATE NOV 83
FIGURE
K-1
envirosphere
company
REPORTED
SMOKEHOUSES & BURIAL SITE
(Ket 038)
ACKERMAN #5
ACKERMAN #6
ACKERMAN #19
ACKERMAN #9
ACKERMAN #10
ACKERMAN #14
BOCA DE QUADRA
WILSON ARM
BAKEWELL ARM
BAKEWELL LAKE
SMEATON BAY
SCALE - MILES
0
1/2
1
2
N

hunting near the coast. For both groups these were short-term, mobile activities which would leave little trace in the archeological record. In the present century both EuroAmericans and Tlingit have trapped and hunted here. The more recent age and more durable nature of materials used in these activities increase the likelihood that evidence of them is preserved. Physical evidence may include cabin or tent remains, trapline trails, and trap sets. Such remains would most likely be found near the coast and up river valleys, but ephemeral camps could also be found higher in the mountains.

Fish Weirs and Fish Camps:

Both the Tsetsaut and the Tlingit camped near the mouths of productive fish streams in the summer. Cultural remains at such sites may include circular stone weirs or remnants of wooden weirs in the tideflats, smokehouses, and kitchen middens.

Hand Logging Sites:

Preferred hand logging sites were atop coastal cliffs from which felled timber would easily slide into the sea. Physical evidence could include the ubiquitous springboard stump as well as logging paraphernalia such as saws, axes, and jacks. The mobile hand loggers often lived aboard their boats, but may occasionally have occupied temporary campsites near the coast.

Criteria for Determining Significance Impacts

The environmental/topographic zones of probability for containing cultural resources constitute one of four factors used to evaluate the consequences of the various project alternatives upon cultural resources. The magnitude, extent, and duration of impacts are other factors that have been considered within the context of cultural resources.

Magnitude:

Magnitude is interpreted to mean the degree to which an activity will damage any cultural resource encountered. Any activity which disturbs the ground's surface at the site of a cultural resource will cause some irreversible damage to that resource. Thus almost all construction activities are considered to be of major magnitude relative to cultural resources. Exceptions to this are bedrock tunnels which will not disturb surface deposits. Theoretically, deposits such as tailings placed on undisturbed surfaces are removable and thus a reversible impact for subsurface resources. Practically speaking, however, they render the cultural resources buried irretrievable and must also be considered an impact of major magnitude. Indirect disturbances caused by increased population in or access to an area will most likely affect only surface resources and thus are considered of moderate magnitude.

Extent:

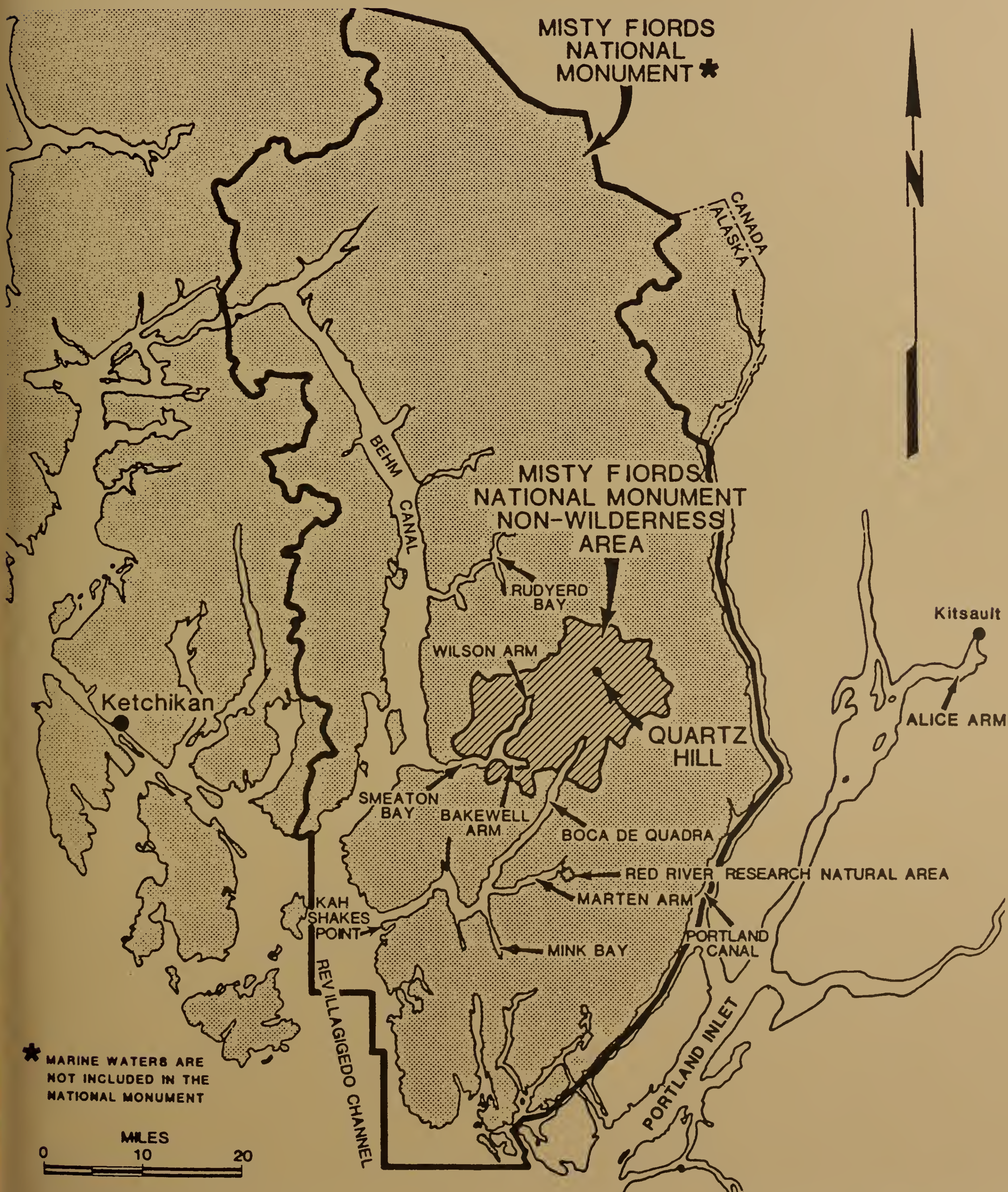
Most cultural resources of the types expected to be found in the area are of very small areal extent. A ground disturbing activity, regardless of its areal extent, can destroy all or a significant portion of any cultural resource it encounters and, thus has been designated as large in extent. Exceptions to this are bedrock tunnels which will not disturb surface deposits and powerlines which cause little surface disturbance. These are considered to be of small and medium extent, respectively. Indirect disturbances caused by increased population in or access to an area are generally diffuse and therefore of medium to small extent.

Duration:

Long-term impact is defined as lasting more than 10 years. Since all damage to cultural resources encountered by construction activities will be irreversible, most construction falls into this category. Medium- and short-term impacts are defined as lasting 1 to 10 years and less than 1 year, respectively. Intermittent duration indicates recurring short-term impacts. The effects of a temporary population increase associated with construction camps fall into the latter three categories.

Note that all of the most severe potential impacts apply to those cultural resources which are encountered during construction activities. A survey of impact areas conducted prior to construction can identify cultural resources in advance of disturbance. Slight alterations in project design may allow the construction to avoid the resource completely and thus considerably reduce the impact. All analyses of project impacts have been done under the conservative assumption that resources will be encountered.

APPENDIX L
LAND USE, WILDERNESS & RECREATION



APPENDIX L - LAND USE, WILDERNESS, AND RECREATION

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I. SUMMARY AND IMPACT RATING DISCUSSION

This appendix is designed to describe in detail the data, methodologies, and calculations supporting the impact estimates and conclusions presented in Sections 4.3.4 tnrough 4.3.6 of the EIS. In general, the contents consist of material that was only summarized in the text. The appendix is organized to first describe the land use, wilderness, and recreation impact ratings, then present further information on data sources, current recreational use of Misty Fiords, and the direct and indirect effects on recreation.

The impact ratings that were presented in Sections 4.3.4 through 4.3.6 are summarized below, along with the constituent ratings of magnitude, extent, duration, and likelihood from which the overall ratings of significance were derived. The uniform approach used in developing these ratings is described in Appendix O.

Variation among the respective land use, wilderness, and recreation impact ratings is based primarily on differences in magnitude and extent of impacts, as most impacts were judged to be both long term and probable. With regard to extent, the major focus was upon Misty Fiords National Monument because it is clearly the unit that would be most affected by the project. Ratings were based largely on the degree to which effects would be localized, the portion of Misty Fiords National Monument that would be affected, and the origin of visitors who would be affected. Direct effects on recreation within the project area would essentially be confined to a small area including parts of Wilson Arm and Boca de Quadra, for example. In comparison, project noise in the Winstanley-Wilson Lake area would affect a significant portion of the Monument, and increased use would affect both local and non-local recreationists throughout the Monument. While most of the project effects would occur only within portions of Misty Fiords, the increased recreational use would be distributed throughout the Monument and the remainder of the Ketchikan management area. These distributional factors were also considered in assessing project impacts.

Magnitude ratings for recreation impacts were assigned on the basis of the number of persons affected and the severity of the effect on them. Noise in the Winstanley-Wilson Lake area would affect a relatively small number of visitors, but the degree of effect on their wilderness experience would warrant a moderate rating. Noise and visual effects in the project area would also be experienced by a relatively small number of recreationists, but due to the less sensitive setting, the magnitude of this impact would be minor. At the other extreme, the changed recreation environment that would result from the townsite option would greatly affect a large number of users, resulting in major impact magnitude.

II. DATA SOURCES

The recreation analysis required data on current use of the Misty Fiords National Monument, and to a lesser extent for the Ketchikan Management Area and Tongass National Forest, plus information on the recreation characteristics of specific user populations. Two primary sources exist for these types of data, which consist of recreation use data available either directly or indirectly through the Forest Service plus survey information applicable to user populations. The general nature, origins, and attributes of these types of data are described below; additional discussion of the use of these data is presented along with the data in Sections 3 through 5 of this appendix.

A. FOREST SERVICE DATA

Identification of current use levels in Misty Fiords and elsewhere on the Tongass National Forest depends upon data maintained by the Forest Service. The major source of information within the Forest Service is the agency's Recreation Information Management (RIM) system. The RIM system is a computerized accounting system used agency-wide to report a variety of recreation planning and mangement information. RIM features generally include data on the capacity (for developed sites), condition, and volume and kinds of use for all sites and areas in the National Forest System. The actual data that are input to the RIM system are collected and reported at the ranger district level. The district reports are forwarded to the RIM Center at each Forest Service Regional Office for cataloging, manipulation, and compilation into various standardized formats. These RIM reports have numerous applications, of which perhaps the most important is the basis for allocating recreation budget funds.

The types of RIM data most commonly used for environmental impact analyses are summaries of annual use by kinds of sites or areas and by activities for various reporting units, usually ranger districts and entire forests. Summaries for sites and areas present estimates of recreation visitor days (RVDs, which are 12-hour units), to the nearest 100 RVDs, for each of several types of developed sites and dispersed areas. Activity summaries are reports of use for each of approximately 20 or more activity categories for an entire reporting unit. Consequently, these RIM reports are not particularly well suited to analysis of small areas such as individual drainages, although the source data upon which the RIM reports are based are somewhat more site-specific.

Accuracy and reliability of RIM data varies considerably between units and among sites within the same unit. Where recreational use can be recorded through some type of registration, such as at fee campgrounds or where wilderness permits are required, RIM data based on such information can be relatively accurate. Conversely, in dispersed areas

where there is no registration system and use is not monitored by backcountry rangers, RIM data are essentially derived from intermittent observation and educated guesses. The latter situation applies to much of the use of Misty Fiords, particularly the use generated by private boaters.

Aggregate use estimates for Misty Fiords are based primarily on mode of access. The Monument staff obtains reasonably accurate visitation data from the commercial sector for cruise ship, tour boat, flightseeing, and air taxi activity. Knowledge about the length of such visits allows these data to be converted into RVD estimates. Contact with air taxi services, U.S. Borax, the Alaska Department of Fish and Game, the Southern Southeast Regional Aquaculture Association, and similar sources provides data on the number and frequency of business-related visits to Misty Fiords, which yields RVD estimates through use of assumptions concerning the proportion of time these visitors devote to recreational activity. For example, in 1983 the U.S. Borax employees residing at the Quartz Hill camp were assumed to recreate an average of .15 RVD (1.8 hours) per person per day during the outdoor recreation season (Barber 1983b).

These sources account for virtually all visitors except for those who reach the Monument by private boat. Private boaters are estimated to account for the largest single portion of total use (over 14,000 RVDs in 1983), and the third largest block of visitors to Misty Fiords after cruise ship and flightseeing visitors (Barber 1984a). These figures are the least reliable of all of the access-based data, because there are no current means for consistently monitoring this type of use. The 1983 data have a reasonably good base of estimation, however, as observer reports for the central portion of the Monument covering most of the days from mid-June through August were obtained from Forest Service employees, tour services, and private boaters contacted in port.

The existing RIM data for Misty Fiords and the remainder of the Ketchikan Area have some significant limitations for analysis of recreation patterns. One major limitation is the lack of adequate time series data. Use estimates for Misty Fiords cannot be "tracked" prior to Fiscal Year (FY) 1981, or compared to figures for other units in the area, due to the administrative actions that created the Monument and reestablished the ranger district system in the Ketchikan Area. On a broader level, RIM data for the Tongass National Forest in general are not comparable over time due to programmatic adjustments in the development of these data. The recreation staff in the Alaska Region has been making a concerted effort to improve the reasonableness of RIM estimates, and correct past problems of overestimation of use and reporting inconsistency between units.

RIM data for aggregate use of the Ketchikan Area over the past five years illustrate these data weaknesses. Total use in the Ketchikan Area was reported at 599,600 RVDs for FY 1978, compared to only 344,700

RVDs for FY 1982 (Forest Service 1983a). This clearly reflects an intentional downward adjustment to correct for previous overcounting, as recreational activity certainly did not decrease by more than 40 percent over this period. A closer inspection of the RIM activity data indicates that the treatment of tour boat, ship, and ferry use (RIM activity code 12.1) is primarily responsible for this inconsistency; this type of activity was estimated at 299,700 RVDs for the Ketchikan area in FY 1978, versus 58,100 RVDs in FY 1982. Given the report from the Ketchikan Visitors Bureau (Rice 1983) that cruise ship traffic doubled from 1979 to 1983, it seems clear that the recent RIM data reflect an attempt to develop more reasonable estimates of actual recreational use by cruise ship and ferry passengers. Nevertheless, comparability problems exist between years and between different reporting units in southeast Alaska. As a result of these inconsistencies, use of RIM data in the Quartz Hill analysis has been restricted in scope.

Forest Service cabin reservation records constitute a separate body of data worthy of mention. A permit and payment of a $10 daily fee are required for use of the public recreation cabins, so cabin reservations provide the means for an accurate record of actual use. Aside from the total use (RVD) input to the RIM reports, cabin reservations also provide data on number of visitors, party size, length of stay, occupancy rates, and local or non-local origin of visitors. Cabin data are not perfect or universal indicators of other use patterns or preferences because cabin users may be a particular type of user and occupancy patterns are subject to cabin availability. However, although minor inconsistencies or incomplete coverage can also occur with this data, in general the cabin reservation data provide the best and most comprehensive statistical data on Misty Fiords users. Cabin data also represent the only applicable time series data, as cabin data for the Ketchikan Area are available for prior years at least through 1972.

B. SURVEY DATA

Two relatively recent surveys, the 1979 Alaska Public Survey and the survey of Ketchikan by Entercom, Inc., provided very valuable information about recreational characteristics of local residents and about user preferences and sensitivities. The Alaska Public Survey (APS) was a multi-agency effort undertaken jointly by the University of Alaska's Institute for Social and Economic Research (ISER), the Forest Service, the National Park Service, the Outer Continental Shelf Office of the Bureau of Land Management, and the Alaska Division of Parks. The APS had a wide variety of objectives involving information on subsistence use, coastal and inland recreation activities, recreation particiption characteristics, opinions on national forest policy issues, and socioeconomic characteristics. As an adjunct of the APS, the Forest Service and Park Service concurrently sponsored the 1979 Alaska Cruiseship Passenger Survey to develop data on a large

non-resident user group. The Entercom survey of Ketchikan was conducted in 1981 with the sponsorship of U.S. Borax, and was designed primarily to study residents' perceptions of life in Ketchikan, attitudes toward Quartz Hill and development-related issues in general, and socioeconomic characteristics.

All residents of southeast, southcentral, and interior Alaska comprised the subject population for the APS. Hour-long interviews were conducted in about 2,900 households within these regions during the spring of 1979 (Alves 1980, p. I-1). Approximately 1,250 interviews were completed in southeast Alaska, representing 73 percent of the households selected for the sample and about 10 percent of all households in the region. Households, and one individual over the age of 18 within each household, were randomly selected for the sample through a multistage cluster sampling design (Clark and Jonnson 1981, p. 12). Survey results were subsequently weighted by computer to correct for differences between communities in initial sampling fraction and fraction of completed interviews, to ensure that the results would accurately reflect the composition of the regional and statewide populations. More detailed information about survey methodology, as well as results, can be obtained from the reports by Alves (1980), Clark (1981), and Clark and Johnson (1981).

The survey iteself was divided into several different series of questions, based on the types of information the respective agencies wanted to obtain. The most useful for the Quartz Hill project analysis were the Section B questions, concerning respondents' participation in saltwater-related activities. Respondents were initially asked how many days they had participated in specific coastal recreation activities within the past twelve months. Subsequent questions were arranged in series to differentiate activity on overnight trips from day trips, and to identify the respondents' favorite sites and most often visited sites for each type of use. For both overnight and day use, respondents were asked to identify on maps sites they had visited within the past year, and were asked about activities engaged in at these sites, mode of travel and travel time, number of trips, party size, and length of stay (for overnight trips only).

The series of questions on favorite overnight places also addressed the attributes of these sites that made them special and investigated respondents' reaction to changes at their favorite site. Respondents were asked whether each of several activities, including clearcuts, mine tailings, shipping traffic, new roads, or several other possible changes would make their favorite site less attractive, and whether they would stop going to the site if any of these changes occurred. A followup question then asked if the respondent had a similar place to go to as an alternative, and how this alternative compared to the favorite place.

Other APS material also yielded useful information for this analysis, particularly questions concerning participation and frequency rates for inland recreation, travel time willingness for weekend recreation, recreational equipment ownership, and personal use of national forest lands and opinions on Forest Service management. In general, the greatest value of the APS material was in providing information on recreation participation characteristics and user sensitivity applicable to the local user population, and the local and regional significance of Misty Fiords. Site- or area-specific application of the APS data was limited by sample size considerations, as the number of respondents identifying favorite or most often visited sites in Misty Fiords was simply too small to provide a basis for reliable conclusions about these sites. For purposes of reference, however, these data have been included in the appendix tables of such APS responses. More specific discussion of the use of APS data is presented along with these data in subsequent sections.

Additional relevant information pertaining to a large segment of the non-resident user population of Misty Fiords was obtained from the 1979 Alaska Cruiseship Passenger Survey, undertaken concurrently with the APS. This survey involved passengers on 121 cruises to southeast Alaska during the 1979 May-to-October cruise season (Koth 1980, pp. 1-4). The survey sample covered passengers from nine separate vessels, six steamship companies, and all three major ports of embarkation (Vancouver, B.C., Los Angeles, and San Francisco). One questionnaire per cabin was distributed on each of 15 separate cruises occurring throughout the season, and 2,844 completed surveys were returned for a 68 percent response rate. The survey was designed to relate passenger characteristics, such as travel patterns, previous experience, and prior expectations, to trip satisfaction and reactions to activities or programs encountered on the cruise. The most direct application of this material concerned the sensitivity of cruise ship passengers to aircraft or shipping traffic and other evidence of resource extraction activities. The survey results also provide information on the residence and socioeconomic characteristics of passengers, shore activities, and the attractions that led passengers to take such a cruise.

The Entercom, Inc. survey of the Ketchikan Gateway Borough was primarily designed to investigate residents' attitudes toward the Quartz Hill project or development-related issues in general, but it also yielded very valuable information about local recreation participation characteristics. This survey was conducted during a two month period in the fall of 1982, following extensive local consultation on questionnaire design and training of locally-hired interviewers. Dwelling units and one resident of at least 18 years of age in each unit were selected randomly according to dwelling unit type, such that the sample accurately represented the housing composition (e.g., single family, mobile home, group quarters, etc.) of the Borough (Entercom, Inc. 1982c, pp. 14-44). A total of 403

interviews were completed, representing 60 percent of the 658 dwelling units originally selected for the sample; 400 completed interviews had previously been established as the necessary sample size.

Survey results with particular application to the Quartz Hill recreation analysis involved recreation participation characteristics and attitudes toward wilderness recreation. One section of the survey included a question asking respondents how important wilderness was to them, followed by a question concerning the importance of solitude in wilderness recreation. Another series of questions addressed outdoor recreation activity, with some of these questions keyed to activity within five specific areas of Misty Fiords. Participation and frequency (number of days per year) rates for twelve recreation activities during the previous 12 months were obtained for recreation in general, followed by participation rates for the same activities in the Unuk, Rudyerd Bay, Wilson Arm, Boca de Quadra, and Portland Canal areas of Misty Fiords. These area-specific participation rates were used in this EIS analysis to develop projections of future recreational use, and provide a check on estimates of current use. Another series of questions concerning attitudes about the two possible access routes provided information about the frequency of visitation to the Boca de Quadra and Wilson Arm areas, and likely changes in visitation rate if the project docking facility were constructed in either area.

III. CURRENT RECREATIONAL USE

Current recreational activity levels within Misty Fiords National Monument, and in other areas as appropriate to the study, were summarized in Section 3.3.3 within the Affected Environment chapter. Supporting data for this summary are presented here for Misty Fiords itself, the local area, and the surrounding region.

A. MISTY FIORDS

As described in the previous section, Forest Service RIM data and cabin reservation data are the two primary sources of quantitative information about current use of Misty Fiords. Pertinent supporting data for these sources are presented in Tables L-1 and L-2.

Table L-1 includes preliminary RIM source data for FY 1983, indicating estimates of use and visitation by major user group and type of access. These use estimates were developed by the Misty Fiords District recreation staff, with input from visitor industry sources, U.S. Borax, and other agencies, and will provide the basis for the final RIM estimates of use by activity and by site or area. As indicated in Table L-1, 88,492 total visits produced 77,500 RVDs of use in 1983. These data include adjustments made by the Regional Office in Juneau to include passive or indirect recreation by cruise ship and Alaska Marine Highway passengers on transits of Revillagigedo Channel and Dixon Entrance. Consequently, the subtotal figures (41,560 RVDs and 39,492 visits) for non-local, local, and business-related use more nearly represent actual engagement in recreation activity within Misty Fiords. Based upon source data from the Monument staff (Barber 1983b), approximately 8,400 of the 9,374 cruise ship and tour boat RVDs represent use on trips to the Rudyerd Bay core area of the Monument.

The data in Table L-1 indicate very substantial differences in length of visit between the different types of user groups. Cruise ship and tour boat visits average 0.4 RVDs or 4.8 hours in length, for example, while the average flightseeing visit is only 1.1 hours long. Conversely, private boaters and cabin users spend roughly 6 RVDs (three full days) in the Monument per visit. Because of user sensitivity levels and these trip characteristics, which are interrelated, the primarily local use component is the most significant in the evaluation of impacts.

Cabin use data for the Ketchikan Area from 1972 through 1983 are presented in Table L-2. These figures are total use (RVD) summaries taken from the Forest Service data sheet for each year. Additional data on number and origin of trips, number of visitors, days used, and total person days were included on the data sheets and were used in the analysis, but have not be reproduced or summarized here.

TABLE L-1

MISTY FIORDS PRELIMINARY 1983 USE AND VISITATION ESTIMATES

User Group/Type of Access	Estimated Use (RVDs)	Estimated Visits
Non-Local Use	9,815	28,234
Cruise ships, tour boats	9,374	23,300
Flightseeing	441	4,934
Primarily Local Use	23,670	5,514
Private boaters	14,188	2,320
Private recreation flights	66	396
Cabin users	5,848	1,033
Resorts, organization sites	1,420	165
General dispersed	2,148	1,600
Business-Related Use	8,075	5,744
Work-related flights	134	1,600
(Borax share)	(91)	(1,100)
Other charter flights	127	927
Worker recreation	3,926	1,921
(Borax share)	(3,060)	(1,500)
Fishing boat recreation	3,888	1,296
SUBTOTAL	41,560	39,492
Alaska Marine Highway	35,940	49,000
TOTAL	77,500	88,492

Source: Barber 1983b, 1984a.

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TABLE L-2

KETCHIKAN AREA
FOREST SERVICE CABIN USE (RVDs)
1972-1983

District/Cabin	1972	1973	1974	1975	1976	1977	1978	1979a/	1980b/	1981	1982	1983
Misty Fiords	3,804	3,980	3,922	4,342	5,026	6,522	6,690	6,124	7,645	7,848	5,238	5,848
Alava Bay	--	--	16	176	338	580	120	310	492	272	386	460
Bakewell Lake	174	280	198	176	180	290	448	392	472	680	406	225
Beaver Creek	246	346	168	248	428	406	480	428	313	252	290	250
Big Goat Lake	206	180	126	90	32	166	244	106	316	648	312	218
Checats Lake	346	150	400	368	592	640	662	324	403	360	286	338
Ella Narrows	350	486	412	510	382	358	440	496	420	548	296	467
Hugh Smith Lake	202	448	388	198	304	338	366	272	329	320	302	364
Humpback Lake	--	--	--	--	--	278	388	500	584	512	414	440
Manzanita Lake	432	146	312	502	482	620	564	638	761	564	278	312
Red Alders	390	534	336	326	418	698	524	384	651	520	584	248
Wilson Narrows	582	426	534	504	442	716	638	640	692	782	430	632
Wilson Overflow	--	--	--	--	--	--	--	--	336	178	--	--
Wilson View	452	412	424	506	492	602	666	802	926	652	414	670
Winstanley Island	124	234	410	528	538	226	440	380	473	1,160	340	694
Winstanley Lake	300	338	198	210	398	604	710	452	477	400	500	530
Ketchikan District (15 cabins)	4,944	4,234	3,730	4,740	4,250	6,460	8,250	na	8,303	9,970	8,986	8,592
North Prince of Wales/Thorne Bay District (13 cabins)	3,644	3,310	3,064	3,490	3,236	4,626	5,784	na	7,919	7,668	7,842	7,612
Craig District (6 cabins)	686	766	1,018	962	784	1,670	1,302	na	2,621	2,040	2,416	2,518
Ketchikan Area Total	14,794	14,650	14,100	16,514	15,766	20,928	23,818	na	26,488	27,526	24,482	24,570

a/ 1979 data for districts other than Misty Fiords could not be obtained.

b/ The 1980 Forest Service data sheet only included cabin use through August 27, 1980; table entries reflect adjustment to account for expected use over remainder of FY 1980 (i.e., through September 1980), based on typical seasonal distribution of cabin use.

Source: Forest Service 1983b.
Barber 1983b

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B. LOCAL AREA AND SOUTHEAST ALASKA

The local area in the context of Misty Fiords recreation is considered to be the Ketchikan Area of the Tongass National Forest. Ketchikan itself is the dominant source of local use of Misty Fiords, but Ketchikan residents also account for much of the use of the Ketchikan, North Prince of Wales/Thorne Bay, and Craig Districts. To illustrate the proportion of local use occurring within Misty Fiords, RIM data on total use and wilderness use are presented in Tables L-3 and L-4, respectively. Conclusions drawn from these data have been summarized in Section 3.3.5.

Additional data from the APS and the Entercom survey were cited in the text in regard to local use. The Entercom data have been included as Table L-11 accompanying the discussion of projections, while APS data concerning the origins of Misty Fiords and other wilderness users are reproduced in Tables L-5 and L-6.

TABLE L-3

MISTY FIORDS AND KETCHIKAN AREA,
TOTAL USE (RVDs), BY KIND OF SITE OR AREA,
FY 1981, 1982

Kind of Site/Area	FY 1981		FY 1982	
	Ketchikan Area	Misty Fiords	Ketchikan Area	Misty Fiords
Developed Sites				
Cabins[a/]	20,400	8,300	18,300	5,600
Resorts	1,000	1,000	1,000	1,000
Boating Sites	2,200	1,300	2,400	1,800
Other	27,000	600	23,500	400
Total Developed	50,600	11,200	45,200	8,800
Dispersed Areas				
Roads	20,000	0	21,900	0
Trails	8,800	2,200	9,800	2,700
Saltwater[b/]	156,100	35,900	160,400	14,300
Freshwater	47,700	8,200	23,000	7,100
General Undeveloped Areas	52,900	7,500	27,700	8,500
Total Dispersed	285,500	53,800	299,500	32,600
TOTAL	336,100	65,000	344,700	41,400

a/ Cabin figures for Ketchikan area only reflect apportionment of 6 hours out of every 24-nour period to dispersed activities away from the cabin itself.

b/ Saltwater data reflect inconsistency in treatment of indirect cruise ship and ferry use, affecting totals.

Source: Forest Service 1983a.

TABLE L-4

MISTY FIORDS AND KETCHIKAN AREA,
WILDERNESS USE (RVDs), BY KIND OF SITE OR AREA,
FY 1981, 1982

Kind of Site/Area	FY 1981		FY 1982	
	Ketchikan Area	Misty Fiords	Ketchikan Area	Misty Fiords
Developed Sites				
Cabins	8,300	8,300	5,600	5,600
Resorts	1,000	1,000	1,000	1,000
Boating Sites	1,300	1,300	1,800	1,800
Other	600	600	400	400
Total Developed	11,200	11,200	8,800	8,800
Dispersed Areas				
Trails	2,100	2,100	2,500	2,500
Saltwater a/	39,200	34,500	49,300	12,400
Freshwater	8,700	8,200	7,000	6,700
General Undeveloped Areas	6,600	5,800	7,300	6,600
Total Dispersed	56,600	50,600	66,100	28,200
TOTAL	67,800	61,800	74,900	37,000

a/ Data reflect inconsistency in treatment of indirect cruise ship and ferry use, affecting totals. If this use is excluded for the Ketchikan area in FY 1982, to make it comparable with Misty Fiords figure, saltwater use would be in vicinity of 25,000 RVDs.

Source: Forest Service 1983a.

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TABLE L-5

ALASKA PUBLIC SURVEY, MISTY FIORDS
VISITATION BY COMMUNITY
1978-1979a/

Community	Percent of Respondents Visiting Misty Fiords	Percent of Misty Fiords Visitation
Ketchikan	14.0	80.4
Juneau	1.3	11.9
Sitka	0.7	2.1
Wrangell	1.4	1.5
Petersburg	1.9	2.2
Haines	2.1	1.0
Skagway	3.1	1.0

a/ Period of coverage is twelve months prior to administration of the APS in April 1979.

Source: Clark and McGowan 1983.

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TABLE L-6

ALASKA PUBLIC SURVEY
OCCURRENCE OF TRIPS TO SPECIFIC AREAS
BY SOUTHEAST ALASKA RESPONDENTS
(PERCENT OF RESPONDENTS)
1978 - 1979[a/]

Visitation	Stikine-LeConte	Admiralty Island	South Baranof	West Chichagoff	Misty Fiords	Glacier Bay
Any trips to area	1.8	9.4	0.8	2.4	4.5	3.7
Any day trips	0.9	5.1	0.3	0.7	1.8	1.5
Any overnight trips	1.2	5.8	0.6	1.9	2.9	2.6
Specific sites:						
Most often overnight	0.7	1.4	0	0.9	0.9	0.8
Favorite overnight	0.5	1.4	0.1	0.2	1.1	0.4
Most often day trip	0.1	1.1	0	0.2	0.2	0.3
Favorite day trip	0.3	1.2	0	0.3	0.1	0.3

a/ Period of coverage is twelve months prior to April 1979.

Source: Clark 1981.

IV. DIRECT EFFECTS ON RECREATION

The general approach required to analyze direct effects on recreation is to identify the areal extent of noise and visual effects, determine the number of users in the affected area, and assess impacts based on the sensitivity of these users. In the recreation analysis, the identification of areal extent of these effects was largely a direct input from the noise and aesthetics studies. Supporting data concerning numbers of users in the affected areas and the sensitivity of these users are provided below.

As described in Section 4.3.3.2, direct project effects would be noticeable in three areas of Misty Fiords, which are the area in the immediate vicinity of project facilities, the Smeaton Bay-lower Behm Canal area, and the area from Winstanley Lake to Wilson Lake (noticeable direct effects of the proposed project would not extend to the Bakewell Lake area). Use estimates for the immediate project area have been fully reported in the text, based directly upon the RIM source data for FY 1983 (Barber 1983b). Use of the Smeaton Bay-lower Behm area cannot be established very accurately, because most activity in lower Behm Canal is pass-through use by boaters and cruise ship passengers on their way to Rudyerd Bay or other destinations. Nearly 12,000 cruise ship and tour boat visitors passed through this area in 1983 (Barber 1983b), although the transit of lower Behm Canal would account for a small portion of total use. Site-specific use of this area would include about 200 RVDs of use associated with the mooring buoy at Alava Bay and 300 to 400 RVDs of use at the Alava Bay cabin. Beyond this figure, recreational activity in this affected area would include a large but unknown portion of private boater visits and a small portion of their total use.

Use of the Winstanley-Wilson Lake area was reported in Section 4.3.5.2 at an expected minimum of about 2,765 RVDs (from 775 visits) per year. This estimate was based upon cabin use data (Forest Service 1983b) and RIM source data for 1983 trail and shelter use (Barber 1983b); because annual use totals for individual cabins fluctuate from year to year, an apparent typical value was taken for each cabin based on actual levels over the past few years. These cabin and trail use data are included in Table L-7. In addition to cabin and trail activity, some dispersed hunting and fishing activity (generally fly-in use not associated with cabins) in this area could also be affected. This use would probably amount to anywhere from 10 to 40 percent of the 2,100 dispersed hunting and fishing RVDs estimated for the entire Monument in 1983 (Barber 1983b), based on the number and distribution of lakes and accessible upland area.

User sensitivity data were derived from APS responses to postulated development-related changes at respondents' favorite overnight coastal recreation sites. The sample of APS respondents indicating their

TABLE L-7

ESTIMATED ANNUAL CABIN AND TRAIL ACTIVITY,
WINSTANLEY-WILSON LAKE AREA

Type of Use	Expected Use (RVDs)	Expected Visitors
Cabins		
Big Goat Lake	300	40
Checats	350	60
Wilson Narrows	625	90
Wilson View	700	85
Winstanley Lake	500	70
Cabin Total	2,475	345
Trails and Shelters		
Punchbowl Lake Trail	100	200
Winstanley Creek Trail	120	200
Winstanley Shelter	70	30
Trail Total	290	430
TOTAL	2,765	775

Sources: Forest Service 1983b, Barber 1983b.

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favorite overnight site was in Misty Fiords was too small to provide meaningful analysis, so response data for Ketchikan residents were relied upon in order to address sensitivity. Given that 80 percent of APS respondents indicating use of Misty Fiords were from Ketchikan (Table L-5), this is a reasonable and appropriate substitution. However, because only 14 percent of Ketchikan residents visited Misty Fiords, it must be acknowledged that Misty Fiords users from Ketchikan may have different sensitivities than Ketchikan respondents in general. In fact, the wilderness designation and character of most of the Monument indicates that Misty Fiords users are probably more sensitive than Ketchikan respondents in general.

The APS response-to-change data for Misty Fiords users, Ketchikan residents, and all southeast Alaska residents are reproduced in Table L-8. As shown in the table, large percentages of all three user groups indicated adverse responses to several of these possible changes, particularly aspects of timber harvesting, mining or drilling, new roads or buildings, and more recreationists. Although the sample of Misty Fiords users is too small for statistical significance, the responses suggest that these users may be more sensitive to change than Ketchikan or all southeast Alaska respondents.

Application of these figures to determine adverse effects on and displacement of Misty Fiords recreationists must be considered approximate, because none of the postulated changes perfectly represents the elements and effects of Quartz Hill project development. The collective effects of the project would include to varying degrees the physical attributes of new logging, offshore oil drilling, shipping traffic, airplanes and helicopters, new buildings, and new roads, as well as other features such as milling equipment noise and stack emissions that are not addressed by the APS questions. It is quite possible that these collective effects would be greater than the most adverse response for any of the constituent changes. Further potential exists for different actual responses because existing conditions and the degree of change are not specified, and because the survey question addresses recreationists' favorite sites. Changes at favorite sites may generate stronger responses than changes at recreation sites in general. Alternatively, because recreationists attach more value to favorite sites they may be less willing to abandon these sites despite adverse changes. If this were the case, recreation sites in general would be abandoned at a greater rate than favorite sites. However, alternative sensitivity data are not available and there is no demonstrable basis for either upward or downward adjustments to the APS data, so these data have been applied directly in order to determine response to project effects.

A final factor relating to sensitivity and impacts is the availability of alternative sites. APS respondents were asked if they had an alternative site similar to their favorite place, and those responding "yes" were asked to compare the similar place to their favorite place.

TABLE L-8

ALASKA PUBLIC SURVEY RESPONSE TO POSSIBLE CHANGES
AT FAVORITE RECREATION SITE
(PERCENT OF RESPONDENTS)

Change/Response	Misty Fiords Users	Ketchikan Residents	Southeast Alaska Residents
New Logging			
Less attractive	81	63	77
Would stop going	81	24	41
Clearcuts			
Less attractive	81	67	80
Would stop going	63	21	37
Log Storage			
Less attractive	100	79	76
Would stop going	38	21	34
Mine Tailings			
Less attractive	81	77	77
Would stop going	38	21	32
Off-Shore Drilling			
Less attractive	81	65	72
Would stop going	38	35	41
Commercial Fishing Boats			
Less attractive	19	27	22
Would stop going	19	15	11
Shipping Traffic			
Less attractive	19	42	43
Would stop going	19	15	16
Airplanes, Helicopters			
Less attractive	38	38	45
Would stop going	19	12	16
New Houses, Buildings			
Less attractive	100	70	80
Would stop going	38	44	43

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TABLE L-8 (Continued)

Change/Response	Misty Fiords Users	Ketchikan Residents	Southeast Alaska Residents
New Roads			
Less attractive	81	56	77
Would stop going	38	29	35
More Recreationists			
Less attractive	100	67	73
Would stop going	56	35	33

Source: Clark and Johnson 1981, pp. 104-109; Clark and McGowan 1983.

These response data, which are included in Table L-9, indicate that most local users have alternative recreation sites that are close to their favorite site in acceptability. The location of each respondent's alternative site was not processed along with these data, however, so it cannot be assumed that all alternative sites would be unaffected by the project.

TABLE L-9

ALASKA PUBLIC SURVEY
AVAILABILITY AND RATING OF
ALTERNATIVE RECREATION SITES
(PERCENT OF RESPONDENTS)

Question	Misty Fiords Users	Ketchikan Residents	Southeast Alaska Residents
Do you have a similar place? (Yes)	81	77	79
How would you rate it compared to your favorite place?			
As good	23	29	38
Almost as good	77	38	39
Acceptable	0	33	21
Not as good	0	0	2

Source: Clark and Johnson 1981, pp. 110-111; Clark and McGowan 1983.

V. INDIRECT EFFECTS ON RECREATION

Analysis of indirect effects of Quartz Hill development required comparison of projections of baseline recreational use of Misty Fiords and the Ketchikan area against projections of increased use attributable to project development. Separate projections were required for different portions of the commute and townsite options, due to different population effects and geographic relationships associated with these options. Supporting data used in the development of these respective projections are presented below, followed by additional material concerning potential use-specific aspects of increased recreational use.

A. COMMUTE OPTION EFFECTS ON MISTY FIORDS

1. Project-Induced Recreational Use

Entercom survey data on recreation participation by Ketchikan residents in specific areas of Misty Fiords were used as the key factor in estimating project-induced recreational use in the Monument under the commute option. These data are reproduced directly in Table L-10. Procedurally, these participation rates were applied to projections of project population effects for the year 1990, 1995, 2,000, and 2005 to derive activity occasions, which were then converted to RVDs on the basis of the typical number of hours per occasion.

Two basic assumptions implicit in this methodology are that the project would have no identifiable net effect on non-local use of Misty Fiords, and that current participation rates for Ketchikan residents are applicable to new Ketchikan residents locating in the area because of the project. With regard to the former, the project would probably have both positive and negative effects upon potential non-local visitors to Misty Fiords. For example, some cruise ship visitors to Ketchikan who otherwise might not have visited Misty Fiords might be prompted to take a flightseeing trip out of curiosity about the mine. Publicity about the project and the project-induced growth in Ketchikan also might increase both non-local awareness of Misty Fiords and the attraction of Ketchikan to non-local users.

Conversely, other cruise ship visitors or non-local boaters would likely avoid Misty Fiords out of disapproval of the environmental changes created by the project. Intuitively, the latter reaction might be common because most out-of-state recreationists come to Alaska for the scenery and pristine landscapes. However, data from the Alaska Cruiseship Passenger Survey indicated that these visitors were not particularly sensitive to most resource-extraction or commercial activities (Koth 1980, pp. 53-54), and most non-local visitors other than flightseers would not be likely to see or hear much evidence of the project. On balance, the net effect on non-local use might be

TABLE L-10

ENTERCOM (1982b) SURVEY
TABLE 14.2,
BREAKDOWN OF MISTY FIORDS
RECREATION BY AREA DURING
LAST TWELVE MONTHS

Table 14.2

Breakdown of Misty Fiords Recreation by Area
During the Last Twelve Months

Number of Residents Participating in:

Recreational Activity	Unuk MF 1*		Rudyerd Bay MF 2		Wilson Arm MF 3		Boca de Quadra MF 4		Portland Local MF 5		Total** MFT
A. Tent camping	3	(1%)***	6	(1.5%)	3	(1%)	3	(1%)	3	(1%)	18
B. U.S. Forest Service cabin camping	4	(1%)	33	(8%)	6	(1.5%)	5	(1%)	5	(1%)	53
C. Backpack camping	2	(.5%)	6	(1.5%)	3	(1%)	3	(1%)	2	(.5%)	16
D. Picknicking	5	(1%)	11	(3%)	4	(1%)	5	(1%)	1		26
E. Fishing	9	(2%)	16	(4%)	27	(7%)	28	(7%)	6	(1.5%)	86
F. Shellfish gathering	6	(1.5%)	11	(3%)	13	(3%)	8	(2%)	4	(1%)	42
G. Boating	31	(8%)	40	(10%)	48	(12%)	34	(8%)	11	(3%)	164
H. Snowmobiling											0
I. Hiking/walking for pleasure	6	(1.5%)	10	(2.5%)	3	(1%)	4	(1%)	4	(1%)	27
J. Big game hunting	7	(2%)	10	(2.5%)	6	(1.5%)	5	(1%)	6	(1.5%)	34
K. Small game hunting	4	(1%)	6	(1.5%)	5	(1%)	1		2	(.5%)	18
L. Cross-country skiing					1						1
TOTAL	77		149		119		96		44		485

* Misty Fiords area designations are per U.S. Forest Service.
** Totals are not true totals because one person may have participated in more than one area or more than one activity. Nonetheless, the "totals" give some idea of numbers of persons utilizing each area.
*** Percent of all adult residents in the Borough.

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slightly positive, but no data could be found that would allow prediction of changes in non-local visitation resulting from project development.

Current participation rates for Ketchikan residents are considered to be the best set of participation data available. The most important advantages of the Entercom participation rates are that they are specific to Misty Fiords, they address a variety of activities rather than aggregate recreation, and they are the most current figures available. Alternative participation data include Entercom data for all recreation by Ketchikan residents and APS participation data for a variety of regional populations, ranging from all southeast Alaska residents to specific communities or community groups. Use of any of these alternatives would either not allow projection detail as to specific activities, or would require an assumption about the share of total local recreation activity that would be "captured" by Misty Fiords. The Ketchikan population may not correspond to the age and sex structure of the project-induced population, but the demographic characteristics of the new residents are unknown; the in-migrating population would likely be slightly younger on average than the Ketchikan population if any difference existed, in which case the projection methodology would cause slight underestimation of future use. Finally, while the new residents would bring with them their current recreation preferences, it is reasonable to assume that they would soon adapt to the locally available recreation opportunities.

Several variations on the basic projection were performed to yield a range of potential increased use and provide a sensitivity check. Nominal low, medium, and high projections were developed by varying factors such as the population base or the number of hours per activity occasion, or by increasing the participation rates over time. Further explanatory comments about the factors employed in the recreation projections are provided below on a point-by-point basis.

Participation Rates

As noted in Table L-10, the area-specific participation rates carry some potential for overestimation because one respondent could have participated in more than one activity or visited more than one area on the same trip. This has been counteracted in the projection methodology by assuming only one trip per year for participation in a given area of the Monument. (APS data indicate that users made 1.8 trips per year to favorite sites in Misty Fiords, while Ketchikan respondents averaged 7 trips per year to their favorite overnight sites.)

For the high projections of future recreational use, participation rates were allowed to increase over time to reflect past and expected future trends in participation and possible shifts in the geographic distribution of use. Based on APS results, Alves (1980, p. IV-10)

reported that annual per capita participation days in southeast Alaska more than doubled from 1967 to 1979 for most activities. Long-range Forest Service (1980b, pp. 99-103) projections of recreation demand are for cumulative increases by the year 2000 of 21 pecent for land-based activities and 34 percent for water-based activities. Consequently, the Entercom particiption rate was conservatively increased by 6 percent (cumulative) in 1990 and 9 percent in 1995 for land-based activities, and by 8 percent and 12 percent, respectively, for water-based activities. Further, participation rates were increased an additional 5 percent in each 5-year projection period to reflect the increasing importance of Misty Fiords as a local recreation resource; as currently pristine areas elsewhere in the Ketchikan area are developed, recreationists would be increasingly likely to shift their activities to remaining wild areas such as Misty Fiords.

Population Projections

The projections of project-induced population growth in Ketchikan attributable to the commute option were as follows:

1990	2,187
1995	2,741
2000	2,740
2005	2,796

For the low projections, these figures were multiplied by a factor of .85 to approximate zero or reduced participation by the very young and very old segments of the population. This adjustment was not employed for the medium and high projections because the in-migrant population is likely to have a disproportionately large share of young adults, who tend to have above-average participation rates.

RVD Conversion Factors

RVD conversion factors are needed to derive estimates of RVDs from projections of activity occasions. The RVD factor for a specific activity is the ratio of the typical number of hours per occasion to 12, the number of hours in an RVD. RVDs factors used for this analysis were as follows:

Activity	Low Projection	Medium and High Projections
Tent camping	1.5	2.0
Cabin camping	7.0	7.0
Backpack camping	1.5	2.0
Picnicking	0.167	0.25
Fishing	0.5	0.80
Shellfish gathering	0.33	0.50
Boating	2.5	3.0
Hiking/walking	0.167	0.25
Big game hunting	0.67	1.5
Small game hunting	0.33	0.5

As indicated above, RVD factors for all activities but cabin use were varied between projections; the average length of stay for Misty Fiords cabin users over the past 10 years was 3.5 days (Forest Service 1983b) or 7 RVDs, so this factor was used throughout. Boat trips to Misty Fiords typically involve 2 or 3 days, but this factor was held lower to work against the doublecounting potential described previously. Further, while a 3-day boat trip would generate 6 RVDs, some of this time would be spent in fishing or other activities aside from boating. Because boat trips are typically for longer than one day, the fishing and shellfish RVD factors incorporate 2 activity occasions for each trip. Although not a direct conversion factor, the high projections also include an allowance for more than one trip per year for hiking and for water-based activities, under the assumption that one trip per year to Misty Fiords would be the maximum expected for backpacking, hunting, and tent or cabin camping.

An example of one projection component is provided in Table L-11, to illustrate exactly how the projections were developed. This example represents the low recreation projection for the Rudyerd Bay area in 1990. Duplicate calculations were performed for the other four areas of Misty Fiords and for all projection years, then repeated for the medium and high projections. In practice, the projections for the periods subsequent to 1990 were generally developed on a population ratio basis (i.e., the ratio of the 1995 population projections to the 1990 population projections) rather than repeating each step of the projection procedure, except where factors other than population were varied. A summary of the results of these projections indicating totals for each activity is included in Table L-12; aggregate projection totals were previously summarized in Table 4-39.

2. Camp Resident Recreational Use

The extent to which workers residing at the Quartz Hill camps recreate in the surrounding area would depend largely upon project policies concerning travel away from the camps and the availability of transportation services. If workers were allowed to moor private boats at the wharf or floating camps, for example, considerable recreational boating, fishing, and related activity could be expected. Conversely, if workers were strongly encouraged to use the camp recreational facilities and were discouraged from recreating away from camp, the activity level in the surrounding area would be less than "normal" for workers in this situation.

Because camp recreation policies have not been established, estimates of potential camp resident use have been developed simply on the basis of an assumed number of hours per week engaged in recreation. During the construction period, the camp population would peak at 1,260 workers in 1987. These workers would be stationed at the camps on a full-time basis, working 6-day weeks and 10- or 12-hour days. If each of these workers spent an average of 4 hours per week over an 18-week

TABLE L-11
LOW RECREATION PROJECTION,
COMMUTE OPTION, RUDYERD BAY 1990

Activity	Percent Participating	Number Participating[a/]	RVD Factor	RVDs
Tent camping	1.5	28	1.5	42
Cabin camping	8.0	149	7.0	1,043
Backpack camping	1.5	28	1.5	42
Picnicking	3.0	56	.167	9
Fishing	4.0	74	.5	37
Shellfish gathering	3.0	56	.33	18
Boating	10.0	186	2.5	465
Hiking/walking	2.5	46	.167	8
Big game hunting	2.5	46	.67	31
Small game hunting	1.5	28	.33	9
				1,704

a/ Equivalent to activity occasions, given allowance of only one trip per year.

TABLE L-12
COMMUTE OPTION RECREATION PROJECTIONS,
MISTY FIORDS ACTIVITY SUMMARY (RVDs) BY YEAR

Projection Year/Activity	Low	Medium	High
1990			
Tent camping	158	242	270
Cabin camping	1,638	1,918	2,138
Backpack camping	128	192	218
Picnicking	18	35	64
Fishing	200	375	748
Shellfish gathering	63	116	229
Boating	1,909	2,691	6,106
Hiking	22	40	77
Big game hunting	107	282	312
Small game hunting	24	45	49
	4,267	5,936	10,211
1995			
Tent camping	193	299	343
Cabin camping	2,030	2,394	2,741
Backpack camping	159	247	282
Picnicking	24	42	84
Fishing	252	472	971
Shellfish gathering	81	145	298
Boating	2,383	3,372	7,931
Hiking	28	48	97
Big game hunting	131	351	401
Small game hunting	32	56	63
	5,313	7,426	13,211
2000			
Tent camping	193	299	360
Cabin camping	2,030	2,394	2,878
Backpack camping	159	247	296
Picnicking	24	42	88
Fishing	252	472	1,020
Shellfish gathering	81	145	313
Boating	2,383	3,372	8,328
Hiking	28	48	102
Big game hunting	131	351	421
Small game hunting	32	56	66
	5,313	7,426	13,872

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TABLE L-12 (Continued)

Projection Year/Activity	Low	Medium	High
2005			
Tent camping	197	205	386
Cabin camping	2,071	2,442	3,082
Backpack camping	162	252	317
Picnicking	24	43	94
Fishing	257	481	1,092
Shellfish gathering	83	148	335
Boating	2,431	3,439	8,919
Hiking	29	49	109
Big game hunting	134	358	451
Small game hunting	33	57	71
	5,421	7,574	14,856

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season (the low estimate) recreating away from camp, the result would be a total of 7,560 annual RVDs. Maximum factors for this activity were assumed to be 7 hours per week and a 22-week season, producing a high estimate of 16,170 RVDs.

The construction camp circumstances would be analogous to those of the townsite option, but the operations camps would represent a different situation. Due to the expected 7-days on, 7-days off rotation and 12-hour shifts, operations workers would have little time available for recreation near the camp, and only half of the total work force would be stationed at the camps at any given time. Further, only workers assigned to the second shift would have many daylight hours nominally available for recreation.

Given these constraints on time availability, potential recreation activity for operations workers was assumed to range from 3 hours to 9 hours over alternative 18- and 20-week seasons. Due to the much lower population of workers able to recreate locally at any given time, these factors result in use estimates ranging from about 800 to 2,900 RVDs in 1990 and 1,000 to 3,800 RVDs in 1995.

Evaluation of these estimates and the impacts resulting from this level of use is uncertain, and should be conducted separately from consideration of the increased local use from Ketchikan. The uncertainty arises because project policies or worker response to site conditions may prevent most of this potential use from occurring. More significantly, this use would be largely confined to areas relatively close to camps, and would therefore occur in areas not likely to be used by other recreationists (due to lack of access and the direct effects of the project). Under these conditions, camp resident recreational use would not have any incremental adverse impacts through crowding and displacement.

If transportation availability allowed residents to range away from the camps, however, the indirect effects on other users would be noticeable. This is particularly true for the construction period, for which the peak camp resident projections are roughly 55 to 80 percent higher than the corresponding 1990 projections of increased use from Ketchikan. If the camps generated such levels of use in outlying areas, the result would be a larger and earlier increase in effective Monument use than would otherwise occur. This effect would decline somewhat as operations workers replaced the construction workers, although the 1,000 to 3,800 RVDs in 1995 would still represent a substantial contribution to total increased use of Misty Fiords.

A final unknown recreation variable concerns the extent to which operations camp residents would use the project as a departure point for extended trips to Misty Fiords during their 7-day long off periods. Again, this would depend largely on the availability of transportation services at the camps. Residents would likely have

little inclination to use the camps as departure points due to logistics problems, but cost and distance factors would probably lead to heavy use of this type if air and water transportation were widely available.

3. Baseline Projections

Projecting baseline recreational use levels required separate estimates for non-local, local, and business-related use occurring in Misty Fiords, for which the results have been summarized in Secton 4.3.5.2. The range of non-local visitation projections was derived by assuming average annual growth rates of 1 percent, 3 percent, and 5 percent, given the lack of definitive forecast from published sources. Local use was projected in the same manner as the commute option increased use, using the population growth rate for the low projection and adding identical participation and distribution shifts for the medium and high projections, respectively. The low projection of business-related use was assumed to be equal to the 1983 level minus 1983 Borax worker recreation (over 3,100 RVDs) and a 30 percent decrease in fishing boat use (to reflect a possible scenario of decreased commercial fishing activity in the region). The constant medium projection represents current use minus the Borax share of current use, while the high projections adds 3 percent annual growth to the medium post-1983 base of 4,924 RVDs. These projections are included in Table L-13. Comparisons of baseline projections and project-induced increased recreational use are presented in Section 4.3.5.2.

B. PROJECT EFFECTS IN KETCHIKAN AREA

Ketchikan residents recreate in areas other than Misty Fiords National Monument, so it was also necessary to project total increased recreational use attributable to project-induced growth in Ketchikan. These projections were based on general (not area-specific) recreation participation characteristics also taken from the Entercom survey of Ketchikan residents (Entercom 1982b, pp. 168-170, 671-718). These survey data indicated the percentage of respondents participating in each of the outdoor recreation activities listed in Tables L-11 and L-12, plus the mean number of days per year participating in each activity. Multiplying the base population by the participation rates and mean annual participation days produced total participation days, which were then converted to RVDs through the appropriate RVD factors. As with the Misty Fiords projections, low, medium, and high projections were developed by varying the inclusiveness of the population base, the RVD factors, and participation rates. A summary of these projections for 1990 and 1995 is provided in Table L-14; estimates for later years were not developed because the base population figures for 2000 and 2005 are very similar to those for 1995, and shifting geographic distribution of use is not of interest in this case.

TABLE L-13

BASELINE RECREATION PROJECTIONS,
MISTY FIORDS
(RVDs) BY YEAR

Type of Use/Projection	1983	1990	1995	2000	2005
Non-Local Use					
Low	9,815	10,523	11,060	11,624	12,217
Medium	9,815	12,071	13,994	16,223	18,807
High	9,815	13,810	17,625	22,494	28,709
Local Use					
Low	23,670	25,871	27,578	29,398	30,545
Medium	23,670	27,682	30,689	34,023	36,410
High	23,670	29,066	33,835	39,386	44,257
Business-Related Use					
Low	8,075	3,849	3,849	3,849	3,849
Medium	8,076	4,924	4,924	4,924	4,924
High	8,075	5,880	6,817	7,903	9,162
Total Use					
Low	41,560	40,243	42,487	44,871	46,611
Medium	41,560	44,677	49,607	55,170	60,141
High	41,560	48,756	58,277	69,783	82,028

TABLE L-14

COMMUTE OPTION RECREATION PROJECTIONS,
KETCHIKAN AREA ACTIVITY SUMMARY
(RVDs) BY YEAR

Projection Year/Activity	Low	Medium	High
1990			
Tent camping	4,424	5,205	5,517
Cabin camping	3,514	4,129	4,376
Backpack camping	2,712	3,189	3,381
Picnicking	2,136	2,514	3,988
Fishing	6,958	10,799	11,662
Shellfish gathering	1,116	1,950	2,105
Boating	11,153	15,892	17,163
Hiking/walking	5,613	9,888	10,480
Big game hunting	1,151	1,697	1,800
Small game hunting	536	831	881
	39,313	56,094	61,353
1995			
Tent camping	5,545	6,523	7,122
Cabin camping	4,404	5,175	5,649
Backpack camping	3,399	3,997	4,365
Picnicking	2,677	3,151	5,148
Fishing	8,720	13,534	15,201
Shellfish gathering	1,399	2,444	2,744
Boating	13,978	19,917	22,371
Hiking/walking	7,035	12,393	13,529
Big game hunting	1,443	2,127	2,324
Small game hunting	672	1,041	1,137
	49,272	70,302	79,590

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As indicated in Table L-14, projected increased use in the Ketchikan area would range from a low of about 39,300 RVDs to a high of about 61,400 RVDs. The corresponding projections for 1995 are 49,300 RVDs and 79,600 RVDs. These figures include the project-induced recreational use that would occur within Misty Fiords, so the projections cited in Table L-14 would have to be subtracted from these totals to derive the increased use on the Craig, Thorne Bay, and Ketchikan Ranger districts.

Baseline projections for the Ketchikan area are included in Table L-15, and are developed from a 1982 base of 286,600 RVDs that excludes ship/yacht/ferry use. The low projection in this case represents recreational use increasing at the rate of population growth, which is 10.6 percent (cumulative) from 1982 to 1990 and 6.6 percent from 1990 to 1995. The medium projection superimposes growth of 8 percent from 1982 to 1990 and 4 percent for 1990 to 1996, to simulate increased participation by local users. The high projection includes an additional 12 percent increase for the first period and 5 percent for the second period, to account for possible increases in non-local use. Comparing the medium projection in each case, the project could generate increased recreational use in the Ketchikan area of over 16 percent above baseline in 1990 and 18 percent above baseline by 1995. The maximum possible effect, derived by comparing the high increased use projection against the low baseline projection, would be an increase of nearly 24 percent by 1995.

C. TOWNSITE OPTION EFFECTS

Projections of increased use of Misty Fiords resulting from implementation of the townsite option required separate estimates for new residents of Ketchikan and the residents of the new town. Rather than repeating the previous projections of increased local use for a smaller population, the ratio of Ketchikan population increases between the two options was applied to the original recreation projections. For example, the population projections (see Section 4.3.1) indicate that Ketchikan growth under the townsite option would be 37.5 percent of the growth resulting from the commute option by 1990, so the previous recreation projections for 1990 were multiplied by .375 to derive increased Ketchikan use with the townsite option. Similar ratios were calculated and applied for the other projection years. The results of these calculations are summarized in Table L-16.

Recreational activity by townsite residents was projected on the basis of the general (not area-specific) participation rates and participation days developed through the Entercom survey of Ketchikan. In general, the participation rates were applied to the townsite population and the result multiplied by the mean number of days per participant per activity to derive total participant days (activity occasions), which were then translated into RVDs through conversion factors. As with the previous projections, low, medium, and high

TABLE L-15

BASELINE RECREATION PROJECTION
KETCHIKAN AREA
(RVDs) BY YEAR

Year	Projection		
	Low	Medium	High
1982	286,600	286,600	286,600
1990	316,980	342,338	383,419
1995	337,901	379,530	446,327

TABLE L-16

PROJECTED INCREASED USE OF
MISTY FIORDS BY KETCHIKAN
RESIDENTS, TOWNSITE OPTION
(RVDs) BY YEAR

Projection	Year			
	1990	1995	2000	2005
Low	1,602	1,498	1,498	1,546
Medium	2,229	2,095	2,094	2,160
High	3,833	3,727	3,909	4,240

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projections were developed by varying participation over time and the percentage of the population included in the population base. RVD conversion factors are also somewhat larger for the medium and high projections, as was done for the commute option.

For illustrative purposes, the calculations for the medium projection of townsite resident use in 1990 are presented in Table L-17. These figures represent total expected annual activity by townsite residents in the activities typically occurring within Misty Fiords, but must be adjusted for activity and geographic relationships to identify the level of activity likely to occur within the Monument itself. For example, participation responses about tent camping largely reflect activity by Ketchikan residents at the nearby developed campgrounds at Settler's Cove and the Ward Lake area; such facilities do not exist in Misty Fiords, so tent camping would effectively be limited to shore camping. Consequently, only 25 percent of the tent camping component of each projection was assumed to occur within Misty Fiords in the medium projections and 50 percent in the high projections. Further, 75 percent of all hiking and picnicking activity was assumed to occur within or very near the townsite itself and would not actually contribute to backcountry use, so this activity was also subtracted. These adjustments reduce the RVD figures in Table L-17 to 813 RVDs for tent camping, 393 RVDs for picnicking, and 1,544 RVDs for hiking, for a total projection of 26,789 RVDs.

Following these adjustments, the net low, medium, and high estimates of townsite-based use potentially occurring in Misty Fiords from 1990 to 2005 are presented in Table L-18. The total range incorporated by these projections is from a minimum of approximately 18,900 RVDs in 1990 to a maximum of about 51,100 RVDs in 2005. The medium projections rise from 26,800 RVDs in 1990 to 39,200 RVDs in 2005. The combined projections for Ketchikan and townsite residents were presented in Section 4.3.5.3, and are only somewhat higher than the figures in Table L-18; the total medium projections range from 29,000 RVDs in 1990 to 41,300 RVDs in 2005.

Townsite resident use would be distributed geographically based on travel mode, travel time to the site, and travel time willingness of the recreationists. Boats would provide the dominant mode of travel, and boaters from any of the alternative townsites would have to travel a minimum of an hour and a half just to reach the nearest Monument boundary. Given the attractiveness of recreation opportunities within Misty Fiords and Ketchikan residents' average weekend travel time willingness of 2.8 hours (Clark and Johnson 1981, p. 153), it is reasonable to expect virtually all of this use to occur within Misty Fiords. From a townsite at Bakewell, for example, boaters could be expected to travel down Smeaton Bay and then north up Behm Canal toward Rudyard Bay and other destinations, rather than travel through more open waters beyond Pt. Alava to generally less scenic or pristine locations. Some recreationists will be willing to travel farther,

TABLE L-17

MEDIUM PROJECTION OF TOWNSITE
RESIDENT RECREATION ACTIVITY
1990

Activity	Percent Partici-pating	Number of Partici-pants[a]	Mean Days	Parti-cipant Days	RVD Factor	RVDs
Tent camping	23	314	6.9	2,167	1.5	3,251
Cabin camping	28	382	4.5	1,719	1.5	2,579
Backpack camping	18	246	5.4	1,328	1.5	1,992
Picnicking	80	1,093	8.6	9,400	0.167	1,570
Fishing	73	997	20.5	20,439	0.33	6,745
Shellfish gathering	54	738	6.6	4,871	0.25	1,218
Boating	78	1,065	23.3	24,815	0.40	9,926
Hiking	80	1,093	22.6	24,702	0.25	6,176
Big game hunting	25	342	6.2	2,120	0.5	1,060
Small game hunting	18	246	6.4	1,574	0.33	519
						35,036

a/ 1990 projection base is 1,366 people.

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TABLE L-18

TOWNSITE RESIDENT RECREATION ACTIVITY
1990-2005
(RVDs)

Projection	Year 1990	1995	2000	2005
Low	18,854	27,169	27,169	27,577
Medium	26,789	38,602	38,602	39,181
High	32,080	47,892	49,620	51,138

however. All southeast Alaska respondents to APS indicated mean weekend travel willingness of 3.2 hours (Clark and Johnson 1981, p. 153), and Misty Fiords users indicated mean travel of 4.7 hours to most often visited sites (Clark 1981, Table 20a). Consequently, from the standpoint of travel time alone, it is conceivable that a significant portion of total townsite use could occur outside of Misty Fiords. Based on attractiveness factors and boaters' preferences for relatively sheltered waters, however, it is more likely that a very high percentage of this use will occur within Misty Fiords. The primary effect of travel time patterns may be to distribute more use to the more remote areas of the Monument, such as northern Behm Canal.

Travel circumstances would vary somewhat between the alternative townsites, but this would probably only alter the distribution of use within the Monument. The mouth of Boca de Quadra would be two hours or more from the Keta townsite for most boaters, so much of the use from this townsite would be confined to the Boca de Quadra drainage; relatively fewer trips would have destinations in Behm Canal or the southern part of the Monument, as these would be trips of several days duration. Little difference in travel ranges would exist between the alternatives on the Smeaton Bay side of the project area. Boaters from any of these sites could reach Walker Cove, Thorne Arm, and the lower part of Boca de Quadra within two to three hours of travel.

D. SPECIFIC INDIRECT EFFECTS

Evaluation of the indirect recreational effects of project development should consider more than the level of overall increased use and possible attendant effects on Monument values. The increased use would not be distributed equally among activities, areas, and time periods, so there would likely be differential effects on specific user groups or reource bases. Consequently, an attempt was made to investigate specific indirect effects relating to sport fish harvest, density of boating activity, and cabin use. Other activities such as shellfishing, beachcombing, hiking, and hunting and camping along shore are also important, but are more difficult to investigate due to a lack of site-specific data.

Although the introduction of a large number of new anglers to the area could intuitively have a significant effect on sport fish harvests and populations, insufficient data on harvest relationships are available to permit estimation of increased catches attributable to project development. (Aside from harvest effects, increased boat density could also have an adverse effect on anglers' satisfaction with their recreation experience.) Fishing success ratios (catch per unit effort) vary widely with species, location, and time of year, making allocation of effort and resulting harvest very difficult to simulate. Further complications arise from temporary and year-around salmon fishing closures of various parts of the Behm Canal area. These area closures could cause an unusual geographic distribution pattern of fishing

effort, or could cause activity to be much lower than projected. As a result of these problems, the effort to quantify increased recreational catch was abandoned.

Precise effects on boat density in Misty Fiords are also difficult to identify, but some very general estimates can be made based on the area-specific recreation activity projections. For the proposed project (area-specific participation rates could not be used for the townsite option projections), the Rudyerd Bay unit would receive from about 500 to 1,500 RVDs of boating use in 1990, and 600 to 2,100 RVDs by 2005. The saltwater area of this unit is approximately 57,000 acres. Assuming there would be 6 RVDs per boat per day (3 users per boat) and that 2 percent of total annual use would occur on the peak day, the low projection for 1990 would correspond to 2 additional peak day boats for the entire unit. This represents a low boat density, although it appears to be about equal to the current average (not peak day) summer boat density for the area (Barber 1983b). At the other end of the scale, the high projection for 2005 would correspond to 7 additional peak day boats in the unit. Total boating activity by townsite residents would range from about 7,000 to 10,700 RVDs in 1990 and 10,000 to 16,100 RVDs in 1995, of which the Rudyard Bay unit could reasonably be expected to receive 25 percent at the very minimum. Boat density effects for the townsite option would therefore likely be considerably above the higher figures cited above for the commute option. The 1995 medium townsite projection of about 15,300 boating RVDs would result in an additional 15 peak day boats in the Rudyerd Bay unit if 25 percent of all boating use occurred in this unit.

Cabin capacity in Misty Fiords would likely be strained as a result of the projected increase in use, at least at some sites. Typical annual use of all cabins in Misty Fiords is currently below capacity, with Wilson View having the greatest utilization rate at about 33 percent of theoretical season capacity. However, because theoretical capacity equates to continual use by 5 persons per cabin, practical capacity is reached at about 40 percent of theoretical capacity.

Projections of increased Misty Fiords cabin use in 1990 resulting from the proposed project range from about 1,600 to 2,100 RVDs, compared to an apparent typical value of about 6,475 RVDs. The corresponding range for 1995 is 2,000 to 2,700 RVDs. Aggregate usage figures from the medium projections for 1990 and 1995 have been apportioned to the 15 cabins (including Wilson overflow) in Table L-19, based on each cabin's share of current use, to illustrate potential effects on cabin capacity. As shown in this table, both Wilson Narrows and Wilson View could be used at more than 40 percent of theoretical capacity by 1995, while six other cabins could be above the 30 percent level. Further calculations for 2005 (not reproduced here) indicate that at the high projection level, use of the two Wilson cabins would exceed 50 percent of theoretical capacity, while Bakewell, Humpback, Manzanita, Red Alders, Winstanley Island and Winstanley Lake would likely be near or

TABLE L-19

POTENTIAL CABIN UTILIZATION
EFFECTS, COMMUTE OPTION
1990, 1995

Cabin	Share of Current Use	1990 Medium Projection	1990 Percent of Theoretical Capacity	1995 Medium Projection	1995 Percent of Theoretical Capacity
Alava Bay	6.2	520	25	550	26
Bakewell	6.2	520	29	550	31
Beaver	4.2	353	17	372	18
Big Goat	4.6	386	21	410	23
Checats	5.4	453	22	479	23
Ella Narrows	6.6	554	26	585	28
Hugh Smith	5.0	420	20	443	21
Humpback	7.3	613	34	647	36
Manzanita	7.7	646	31	683	33
Real Alders	8.1	680	32	718	34
Wilson Narrows	9.7	814	39	860	41
Wilson Overflow	1.9	159	8	169	8
Wilson View	10.8	906	43	958	46
Winstanley Island	8.5	713	30	754	31
Winstanley Lake	7.7	646	31	683	33
TOTAL		8,393	27	8,869	29

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above the 40 percent level. Cabin use in Misty Fiords under the townsite option would likely be about 10 percent higher than corresponding outcomes for the proposed project under the low and medium projection scenarios, and 20 to 30 percent greater under the high projection scenario.

The Quartz Hill project would also result in a substantial increase in cabin use elsewhere in the Ketchikan area, particularly in the case of the commute option. As indicated in Table L-14, increased cabin use attributable to the project could range from about 3,500 to 4,400 RVDs in 1990 and 4,400 to 5,600 RVDs by 1995. The medium projections of 4,100 RVDs in 1990 and 5,200 RVDs in 1995 represent respective increases of about 17 percent and 21 percent over the 1983 Ketchikan area total of approximately 24,600 cabin use RVDs. The 1990 and 1995 baseline levels would be higher than the latter figures, but the proposed project would clearly lead to a significant increase in local cabin use.

The projected increases in cabin use in both Misty Fiords and the Ketchikan area, particularly in the former, would have several types of adverse effects. Recreation facilities such as campgrounds or cabins are generally considered to be heavily used when occupancy exceeds 40 percent of theoretical capacity. This is because theoretical capacity defines complete and continuous occupancy over the entire managed season, while in actual use party size is often less than capacity and use tends to be concentrated on weekends and during the peak season. Consequently, a cabin with a theoretical season capacity of 2,100 RVDs (a 210-day season) could accommodate 900 RVDs during the 90-day summer season if it were fully occupied (by 5 people) every day; at the average party size of 3.5 people, maximum summer use would be 630 RVDs or 30 percent theoretical seasonal capacity.

In view of these capacity considerations, project-induced cabin use would lead to a decrease in cabin availability, particularly for the most heavily used cabins in Misty Fiords and popular cabins elsewhere in the Ketchikan area. This would in turn cause current cabin users to alter their weekly or seasonal patterns of use, shift their activity to less attractive cabin locations, or possibly to abandon cabin camping. Aside from their loss of recreation experience value, displaced users experience various degrees of alienation and resentment that can lead to conflict and vandalism or other antisocial behavior (McGowan 1984).

The implications of these effects on cabin capacity can be interpreted in different ways. The general or expected response would be that capacity should be increased by constructing new cabins to relieve the use pressure, preferably at locations that provide very similar opportunities. Capacity expansion would have to be done in consideration of the effects of more cabins on existing wilderness values, however, which could raise a variety of issues. Construction of new cabins also may not prevent the displacement of long-time cabin users, who might likely feel that the influx of new residents had deprived them of access to their preferred sites.

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APPENDIX M
AESTHETICS

APPENDIX M

AESTHETICS

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LIST OF FIGURES

APPENDIX M

I. SUMMARY

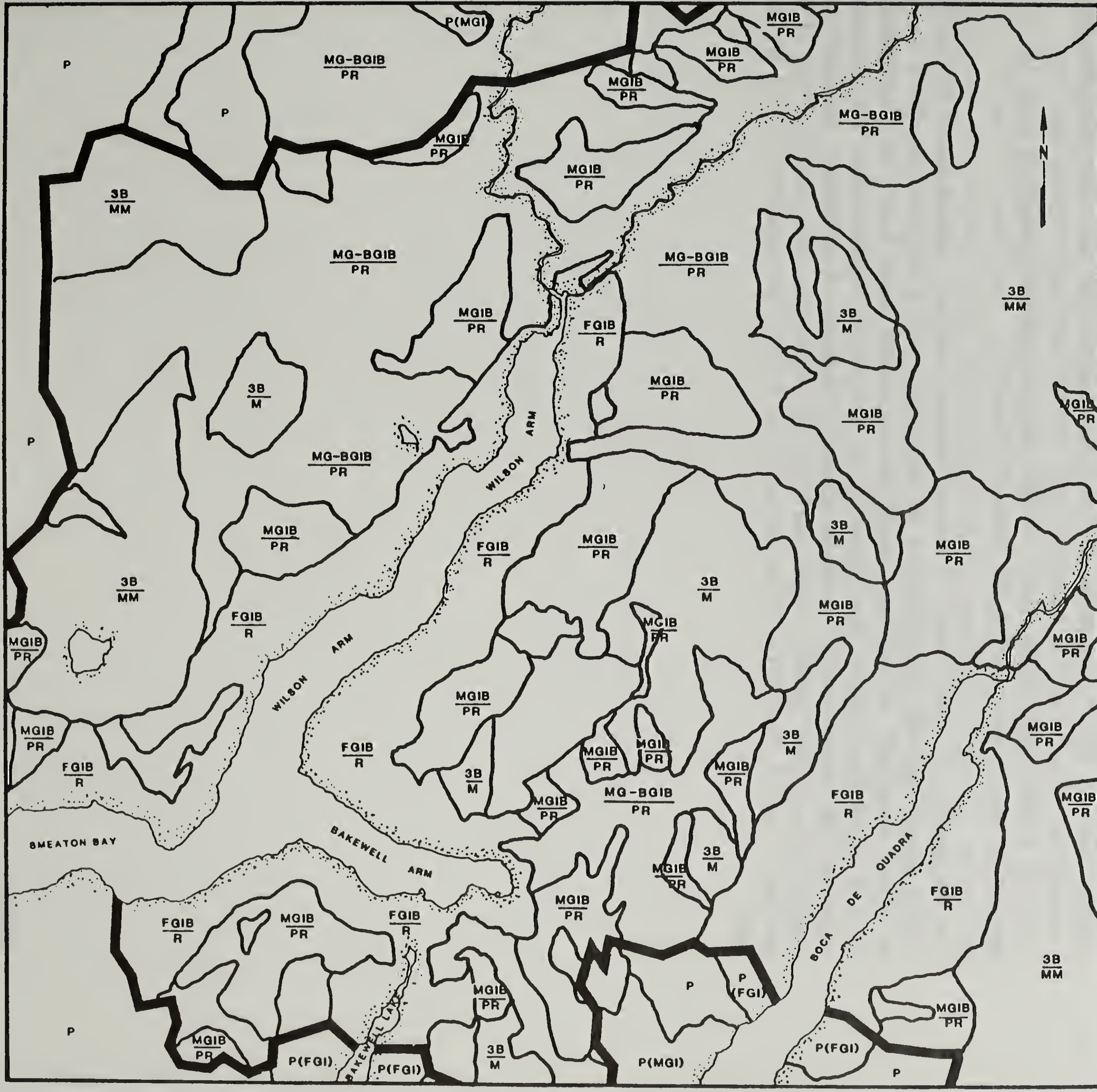
Appendix M presents the data and analytical approach used to assess the potential visual impacts resulting from the development of the proposed project and of each of the alternatives. Visual impacts were assessed based on an individual evaluation of the impacts of each of the major components. The impacts were assigned a significance level, ranging from insignificant to very significant. The significance ratings were based on the viewer's concern for the visual environment, the frequency and duration of viewing activity, the visibility of project features from sensitive viewing areas, and the degree to which project induced landscape alterations conform to the Forest Service visual quality management objectives.

The significance values assigned to each project concept varied by component. The proposed action resulted in overall moderately significant visual impacts to viewers of the project area. Very significant visual impact ratings resulted from the inclusion of on-land tailings disposal or the establishment of a permanent townsite. These two components were the key factors contributing to the very significant visual impact ratings that were assigned to the Tunnel Creek mill and North Meadow mill alternatives. The addition of a permanent townsite to the proposed project concept would substantially increase the visual impacts to a level warranting a very significant visual impact significance rating. At the other end of the spectrum, the Beaver Creek mill with Wilson Arm or Boca de Quadra tailings disposal and the North Meadow Mill Boca de Quadra tailings disposal are alternatives that would result in the least significant visual impacts.

II. DATA SOURCES

The visual impact assessment relied primarily on the Forest Service Visual Resource Management (VRM) System (Forest Service 1974). The visual quality management objectives that have been assigned to the project landscapes, as shown in Figure M-1, provide an inventory of landscapes having distinctive natural features and high viewer sensitivity. Landscapes within the project boundary that are considered sensitive to viewing activity are concentrated along the shorelines of the main water courses leading into the project area. The shorelines surrounding both Wilson Arm and Boca de Quadra are assigned "retention" visual quality management objectives when viewed within foreground distance zones and "partial retention" when viewed within middleground distance zones.

An additional data source used in this anaysis was the Technical Memorandum on the aesthetic impacts of the Quartz Hill Molybdenum Project prepared for the Draft Environmental Report (Bechtel Civil and Minerals, Inc. 1983b). This document delineates areas of visual intrusion, the total acreage from which an unobstructed line-of-sight to any or all project features is possible. Areas of visual intrusion were determined for the various components of the project. Although the size of an area of visual intrusion is an important factor, the significance of the visual impacts created by the project's development corresponds to viewing activity (frequency, duration, and viewing point location) as well.



LEGEND

VISUAL QUALITY OBJECTIVES

P	PRESERVATION (Applies to wilderness areas)
FGIB / R	FOREGROUND ZONE SEEN FROM SURFACE USE AREAS-VARIETY CLASS B / RETENTION
MGIB / PR	MIDDLEGROUND ZONE SEEN FROM SURFACE USE AREAS-VARIETY CLASS B / PARTIAL RETENTION
BGIB / PR	BACKGROUND ZONE SEEN FROM SURFACE USE AREAS-VARIETY CLASS B / PARTIAL RETENTION
3B / M	UNSEEN AREAS - VARIETY CLASS B / MODIFICATION
3B / MM	UNSEEN AREAS - VARIETY CLASS B / MAXIMUM MODIFICATION

0 1/2 1 2 3 4

SCALE - MILES

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

VISUAL QUALITY
MANAGEMENT LANDSCAPE
CLASSIFICATIONS

SOURCE FOREST SERVICE DATE 1981c

FIGURE M-1

envirosphere company

The Forest Service VRM System provides a frame of reference for analyzing the viewing activity in the project area. The frequency of viewing the project landscapes, as well as the duration of the views and likely viewer locations, were all factors considered by the Forest Service prior to assigning visual quality management objectives to these landscapes. The visual quality management objectives are intended as guidelines for determining acceptable levels of landscape alteration. Each landscape is evaluated in terms of its ability to absorb landscape alterations and simultaneously retain its natural scenic qualities. Both the area of visual intrusion and the compatibility of the project-induced landscape alterations with the assigned visual quality management objectives were evaluated to determine the significance of visual impacts of the project.

The significance of the visual impacts of each project component varied depending on the number and frequency of viewers that were likely to observe the project structures and roads. Viewing activity of project features in Wilson Arm and the Tunnel Creek drainage is likely to be higher due to the frequency of travelers along Wilson Arm enroute to recreation sites in the Rudyard Bay and Wilson Lake areas and to fishing sites in Wilson Arm. Travel by both boat and airplane is higher in Wilson Arm than in Boca de Quadra.

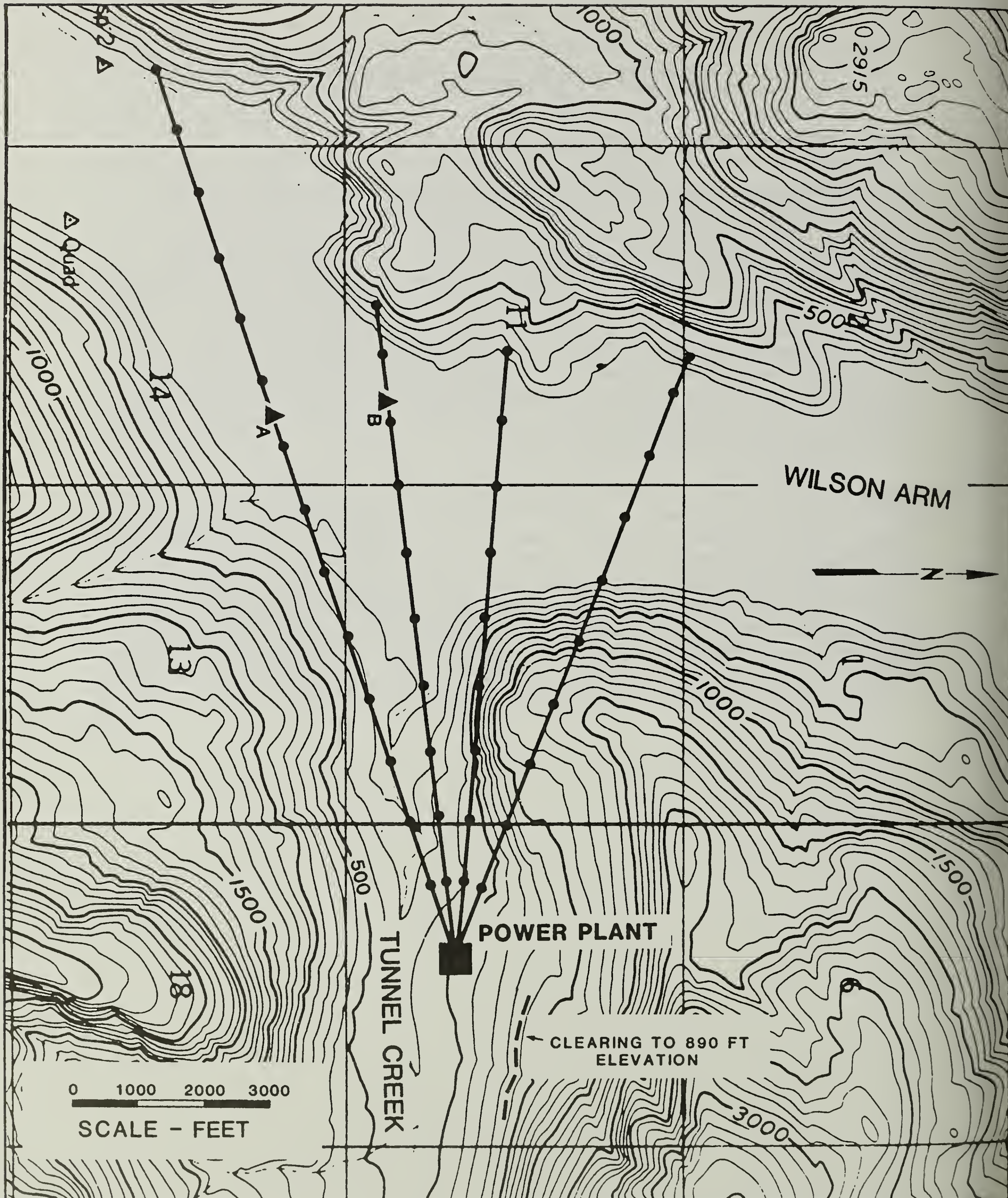
The majority of the Tunnel Creek drainage can be viewed when traveling north along Wilson Arm by boat or airplane. The degree to which proposed project structures would be obscured from the viewer depends on the elevation where the structures would be located and the degree of clearing required to develop the mill site. A viewshed analysis was conducted of the Tunnel Creek valley to determine the visibility of the project's mill facility structures from likely viewpoints along Wilson Arm.

III. METHODOLOGY, ASSUMPTIONS, AND TECHNICAL ANALYSIS

TUNNEL CREEK VIEWSHED ANALYSIS

The Tunnel Creek viewshed analysis was conducted to determine the visibility of the plant structures and define the boundaries of a viewshed from viewpoint locations on Wilson Arm. It was assumed that an unobstructed viewing range from the plant site location toward Wilson Arm would be reciprocal from viewpoint locations on Wilson Arm looking toward the Tunnel Creek valley. Two viewpoints were selected at the Tunnel Creek processing facilities site to measure the visibility of the project features. The first viewpoint represented the highest elevation at the site where clearing was likely to occur. The second viewpoint represented an elevation level equivalent to the midpoint of the highest structure, the power plant stack, which would be the focal point of the site.

Using a USGS topographic map (scale of 1 in. = 2,000 ft) with 100-ft-interval contours, a direct line-of-sight analysis was conducted along four rays drawn from the power plant viewpoint location extending to the west shoreline contour of Wilson Arm. The rays, as shown in Figure M-2, were drawn within the natural boundaries of the north and south slope of the Tunnel Creek drainage dividing the viewshed into equal parts. The visibility of project features from viewpoint locations at 1,000 ft. intervals was determined along each of the four rays.



LEGEND

▲ VIEWPOINT

—●—●— VIEWSHED ANALYSIS RAY

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
QUARTZ HILL MOLYBDENUM PROJECT
MINE DEVELOPMENT EIS

TUNNEL CREEK
VIEWSHED ANALYSIS

SOURCE ENVIROSPHERE DATE 1984

FIGURE
M-2

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A Division of EBASCO SERVICES INCORPORATED

The average 100 ft height of the trees was included in each calculation. The power plant stack was estimated to be 130 feet high. The elevation of the midpoint of the stack was calculated by adding half the height of the power plant stack plus the height of the plant building structure to the elevation level of the proposed power plant location.

Views observed from a boat approaching the Tunnel Creek valley area from the south are generally obstructed by the southern valley walls of the drainage area. Upon reaching the viewpoint corresponding with Viewpoint A shown in Figure M-2, viewing of the landscapes at the proposed mill site location becomes possible at the 890 ft elevation. Therefore, any project structure or clearing activity at this elevation would be visible to the viewer. However, clearing is not likely to be necessary above the 850 ft elevation level. The power plant structure, its height reaching the elevation level equivalent to 630 ft, would not be visible from this viewpoint. Potential viewing of the power plant structures increases when views toward Tunnel Creek are observed from within 1,600 ft of the west shoreline of Wilson Arm. From this general location views will include the power plant stack and plume and additional project features and clearing at higher elevations. Viewing activity from locations near the west shoreline of Wilson Arm is likely to be limited to fishermen or boating recreationists.

The power plant would be visible when viewed from an airplane at 275 ft altitudes directly above the viewpoint location in Figure 4-13a (Viewpoint A). Airplanes typically fly at 3,000-4,000 ft altitude.

Potential viewing of the project structures increases as the viewer travels north as well as west of the above viewpoint location. From a second viewpoint location located further north, Viewpoint B, project structures at the 560 ft elevation and above are visible. These views would include a majority of the structures to be located at the mill site, including but not limited to the power plant, service building, crushed ore storage, and portions of some of the roadways. Views observed from viewpoints located farther north along Wilson Arm are soon impaired by the existence of the north ridge defining the Tunnel Creek drainage.

APPENDIX N
RATING OF IMPACTS

APPENDIX N

RATING OF IMPACTS

A standard method of rating impacts was utilized in this EIS. The method was designed to provide consistency in impact evaluation throughout the EIS and among the many preparers and contributors. A five step system was used with the steps as follows:

(1) A list of potential project impacts was made for each resource and for each project alternative concept. No impact ratings were assigned, the impacts were simply listed.

(2) Four component levels of impact were used: magnitude or potential (major, moderate, minor), extent (large, medium, small), duration (long term, intermittent, medium term, short term), and likelihood (probable, possible, unlikely). As a general guideline, subject to modification by individual disciplines, long term was defined as over 10 years, medium term as 1 to 10 years, and short term as less than 1 year. Intermittent duration indicates a recurring short term impact.

(3) The four component levels of impact were determined for each impact on the list developed in Step 1.

(4) Three adjectives were used to rate the list of impacts: very significant, moderately significant, and insignificant.

(5) Table N-1 was used to rate each impact based on the component levels estimated in Step 3. The four component levels were matched horizontally across the table to determine the level of impact The completed impact assessments are included in this section and were used to write the impacts section of this EIS.

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TABLE N-1

CRITERIA FOR RATING IMPACTS

Impact Rating	Level of Impact			
	Magnitude	Extent	Duration	Likelihood
Very Significant				
	Major	Large or Medium	Any level	Probable
	Major	Large or Medium	Long term	Possible
Moderately Significant				
	Major	Any level	Medium term, intermittent, or short term	Possible
	Moderate	Large or Medium	Any level	Probable
	Major	Small	Any level	Probable
	Moderate	Large	Any level	Possible
	Moderate	Medium or Small	Any level	Possible
	Moderate	Small	Any level	Probable
	Major	Large	Any level	Unlikely
	Major	Medium or Small	Long term	Unlikely
	Minor	Large	Any level	Probable
	Minor	Medium or Small	Long term	Probable
	Major	Medium or Small	Medium term, intermittent, or short term	Unlikely
Insignificant				
	Minor	Medium	Medium term or intermittent	Probable
	Minor	Large	Any level	Possible
	Minor	Medium or Small	Long term	Possible
	Moderate to Minor	Any level	Any level	Unlikely
	Minor	Medium	Short term	Probable
	Minor	Small	Medium term, intermittent, or short term	Probable
	Minor	Medium or Small	Medium term, intermittent, or short term	Possible

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APPENDIX O
U.S. ARMY CORPS OF ENGINEERS 404 (b)(1) EVALUATION

APPENDIX O

EVALUATION OF THE DISCHARGE OF DREDGED AND FILL MATERIAL
IN ACCORDANCE WITH SECTION 404(b)(1) GUIDELINES

APPENDIX O
EVALUATION OF THE DISCHARGE OF DREDGED AND FILL MATERIAL IN ACCORDANCE WITH SECTION 404(b)(1) GUIDELINES

SUBPART A GENERAL

Dredged and fill material should not be discharged into the aquatic ecosystem unless it can be demonstrated that such a discharge would not have an unacceptable adverse impact either individually or in combination with other known and/or probable impacts of other activities effecting the ecosystem of concern.

A Permit for Discharge of Dredged and Fill Material from the Corps' District Engineer, Alaska District, would be required under Section 404 of the Clean Water Act. The Corps approves discharges at particular sites through application of its 404(b)(1) Guidelines. The Corps also conducts a Public Interest Review to ensure that the discharge would comply with other regulatory requirements and be in the public interest. EPA reviews the permit application and provides comments to the Corps. The Corps, in applying the 404(b)(1) Guidelines, must determine the potential short-term or long-term effects of the proposed discharge on the physical, chemical, and biological components of the aquatic environment. The proposed discharge must comply with the following restrictions:

- No discharge of dredged or fill material will be permitted if there is a practicable alternative that would have a less adverse impact on the aquatic ecosystem.
- The discharge of dredged or fill material cannot:
  - Violate any applicable state water quality standard
  - Violate any applicable toxic effluent standard
  - Jeopardize a threatened or endangered species
  - Adversely impact any marine sanctuary designated under the Marine Protection, Research, and Sanctuaries Act
- No discharge will be permitted that will cause or contribute to significant degradation, including:
  - Human health and welfare
  - Life stages of aquatic life and other wildlife dependent on aquatic ecosystems
  - Aquatic ecosystem diversity, productivity, and stability
  - Recreation, aesthetic, and economic values

The evaluation of proposed discharges considers the effects on:

- Physical substrate
- Water circulation, fluctuation, and salinity

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- o Suspended particulates/turbidity
- o Contaminants (introduction, relocation, or increase)
- o Aquatic ecosystem and organisms
- o Proposed disposal site (mixing zone)

The evaluation also considers cumulative and secondary effects.

SUBPART B COMPLIANCE WITH GUIDELINES

The proposed Quartz Hill Molybdenum Mine Development Project would involve a discharge into a special aquatic site. A description of the proposed project and alternatives evaluated for impact analysis is found in Section 2.0 and Appendix A of this EIS. There are no project development alternatives which would achieve the project purpose that do not involve discharge of fill material into waters of the United States. The No Action Alternative is discussed in Sections 4.1 through 4.3 of this EIS.

The discharge of fill material will have to be in compliance with State Water Quality Standards and cannot violate applicable Federal toxic effluent standards pursuant to Section 307 of the Clean Water Act (40 CFR 219).

The use of fill in the project or any of the project alternatives would not jeopardize the continued existence or critical habitat of species listed under the Endangered Species Act of 1973 (16 USC 1531 et seq.) nor would the project violate any requirement established by the Secretary of Commerce to protect any marine sanctuary. The consultation under Section 7 of the Endangered Species Act with the U.S. Fish and Wildlife Service is discussed in Sections 3.2.5 and 4.2.5 of this EIS.

As determined in Section 4.0, Environmental Consequences, of this EIS, the use of fill in specific components of the project, or any of the alternatives, would not contribute to significant degradation of waters of the United States.

Appropriate and practical steps have been identified in Section 4.4 which would minimize potential adverse impacts of the project on the aquatic ecosystem. These mitigating measures would be incorporated into the project design or would be required by permit conditions or other agreements.

SUBPART C PHYSICAL AND CHEMICAL IMPACTS

Pertinent information about impacts of the proposed project and alternatives are described in the following sections of this EIS.

		EIS Sections
230.20	Substrate	4.1.2, 4.1.4, 4.1.7, 4.2.1-4.2.3
230.21	Suspended particulates/turbidity	4.1.5-4.1.7, 4.2.1, 4.2.2
230.22	Water	4.1.3-4.1.5
230.23	Current patterns and water circulation	4.1.3, 4.1.6
230.24	Normal water fluctuations	4.1.3, 4.1.6
230.25	Salinity gradients	4.1.6

SUBPART D BIOLOGICAL IMPACTS

Pertinent information about impacts of the proposed project and alternatives are described in the following sections of this EIS.

	EIS Sections
Threatened and Endangered Species	3.2.5, 4.2.5
Aquatic Organisms	4.2.1, 4.2.2
Wildlife	4.2.4

SUBPART E POTENTIAL IMPACTS ON SPECIAL AQUATIC SITES

Wetlands and vegetated shallows are the only special aquatic site which would be affected by the project. Discussions about impacts of the project and alternatives on values associated with wetlands are found in the following sections of this EIS.

	EIS Sections
Wetlands	4.2.3
Vegetated Shallows	4.2.1-4.2.3
Wildlife	4.2.4

SUBPART F POTENTIAL EFFECTS ON HUMAN USE CHARACTERISTICS

Pertinent information about impacts of the proposed project are described in the following sections of this EIS.

		EIS Sections
230.51	Recreational and commercial fisheries	4.2.1-4.2.2, 4.3.3
230.52	Water-related recreation	4.3.5, 4.3.6

		EIS Sections
230.53	Aesthetics	4.3.7
230.54	Parks, national and historical monuments, national seashores, wilderness areas, research sites and similar preserves	4.3.5, 4.3.6

SUBPART G EVALUATION AND TESTING

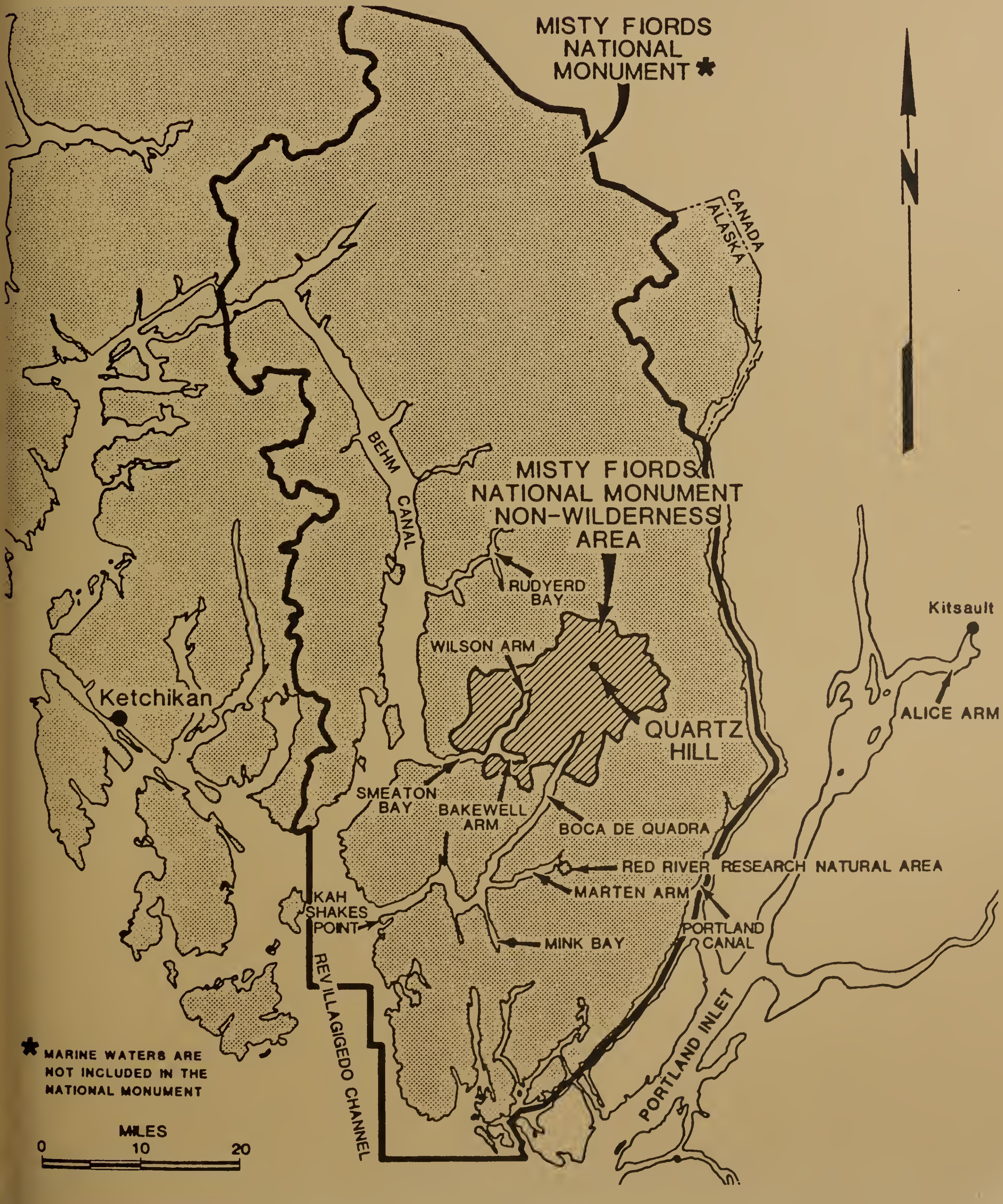
The source and type of fill material that would be used to develop the proposed project or any of the alternatives is described in Appendix A of this EIS. The type of fill materials used are clean shot rock and material excavated from several quarry areas within the disturbed project area.

The possiblity that the proposed discharge material is a carrier of contaminants is very unlikely. Based on this evaluation, there is little likelihood that discharges of fill associated with the applicant's proposed project or any practicable alternatives would result in contamination of the aquatic ecosystems; therefore, no testing would be required.

SUBPART H ACTION TO MINIMIZE ADVERSE EFFECTS

Those practicable actions which are not part of the applicant's current proposal but could be taken to minimize significant adverse effects of the proposed project are described in Section 4.4 of this EIS.

APPENDIX P
U.S. ARMY CORPS OF ENGINEERS PUBLIC NOTICE



US Army Corps
of Engineers
Alaska District

Regulatory Branch
Post Office Box 898
Anchorage, Alaska 99506-0898

Public Notice of Application for Permit

PUBLIC NOTICE DATE: October 21, 1988

EXPIRATION DATE: November 20, 1988

REFERENCE NUMBER: 2-840015

WATERWAY NUMBER: Smeaton Bay 5

REVISION

On July 20, 1984, the Alaska District Corps of Engineers (Corps) published a Public Notice for an application received for a Department of the Army (DA) permit from the United States Borax and Chemical Corporation (U.S. Borax) on behalf of the Pacific Coast Molybdenum Company. The applicant proposed to construct various facilities associated with the development and operation of a proposed molybdenum mine and ore processing plant. The public notice was distributed with the Forest Service's Quartz Hill Mine Development draft Environmental Impact Statement (EIS), Appendix Q.

On August 17, 1984, a revised public notice was issued that discussed additional water supply dams; resolving the issue of applicability of Title XI of the Alaska National Interest Land Conservation Act (ANILCA) to this project; establishing the date and location for the draft EIS joint public hearing; and increasing the comment period length for the revised Public Notice 2-840015 and the draft EIS.

On May 1, 1987, the Alaska District Corps of Engineers published a revised Public Notice which was distributed with the Forest Service's revised draft EIS, Appendix P.

On June 3, 1987, the Corps published a revised Public Notice stating a joint permit processing procedure for log transfer facilities had been established between the Corps and the U.S. Environmental Protection Agency (EPA). After discussions with the applicant and EPA, the Corps has decided that should the DA permit be issued for the proposed mine development and there remains a need for the proposed temporary log transfer facility, then the special joint process would proceed. The Public Notice also indicated that the proposed discharge of tailing in navigable waters of the United States will require DA authorization under Section 10 of the Rivers and Harbors Act of 1899 and the discharge of overburden from the mine in waters of the United States will require DA authorization under Section 404 of the Clean Water Act. Lastly, the Public Notice stated that at no time during the public

comment period is the Corps a proponent of any regulatory action and can not disclose an Agency Preferred Alternative in an EIS. However, the Corps would announce an Environmentally Preferred Alternative in the final EIS.

Since the 1987 public notice, the applicant has proposed additional changes in the project. The Corps did not have the opportunity to review the complete final EIS prior to publication and distribution, therefore it was not possible for a determination and inclusion of the Corps' Environmentally Preferred Alternative. The Environmentally Preferred Alternative will be included in the Corps' record of decision (ROD). This Public Notice (Reference No. 2-840015) supersedes all other notices for the proposed actions identified under 071-OYD-2-840015, unifies the previous Public Notice information, and revises the proposal.

APPLICANT: United States Borax & Chemical Corporation on behalf of the Pacific Coast Molybdenum Company, Post Office Box 75128, Sanford Station, Los Angeles, California 90075-0128.

LOCATION: In portions of Wilson Arm of Smeaton Bay, including the following tributaries and/or wetlands of Wilson River, Blossom River, Float Creek, Hill Creek, Beaver Creek Tributaries, Tunnel Creek, No. 3 Creek, Raspberry Creek, No. 1 Creek, Beaver Creek, and White Creek, of the non-wilderness portion of Misty Fiords National Monument, Tongass National Forest, approximately 45 miles east of Ketchikan, Alaska.

A. Transportation and Utility Systems:

1. MARINE TERMINAL: Sec. 14, T. 75 S., R 97 E., C.R.M.

2. ACCESS ROADS: Sec. 1, 12, 13, 14, T. 75 S., R 97 E., C.R.M.
   Sec. 27, 28, 29, 31, 32, 34, T. 74 S., R. 98 E., C.R.M.
   Sec. 7, 8, T. 75 S., R. 98 E., C.R.M.
   Sec. 36, T. 74 S., R. 97 E., C.R.M.

3. BLOSSOM RIVER WATER INTAKE:
   Sec. 36, T. 74 S., R. 97 E., C.R.M.

4. WATER SUPPLY PIPELINE:
   Sec. 36, T. 74 S., R. 97 E., C.R.M.
   Sec. 1, 12, 13, T. 75 S., R. 97 E., C.R.M.
   Sec. 7, 8 T. 75 S., R.98 E., C.R.M.

5. WATER SUPPLY DAMS:
   Sec. 8., T. 75 S., R. 98 E., C.R.M.
   Sec. 27, 28, T. 74 S., R. 98 E., C.R.M.

6. TAILINGS OUTFALL:
   Sec. 14, T. 75 S., R. 97 E., C.R.M.

B. Other Facilities and Work:

1. SEDIMENT CONTROL DAMS:
Sec. 6, T. 75 S., R. 99 E., C.R.M.
Sec. 25, 27, 28, T. 74 S., R. 98 E., C.R.M.

2. MINE PERSONNEL HOUSING:
Sec. 28, T. 74 S., R. 98 E., C.R.M.
Sec. 7, T. 75 S., R. 98 E., C.R.M.

3. MINE SERVICE FACILITY:
Sec. 34, T. 74 S., R. 98 E., C.R.M.

4. TAILINGS DISCHARGED INTO NAVIGABLE WATERS OF THE U.S.:
Sec. 14, 15, 21, 22, 27, 28, T. 75 S., R. 97 E., C.R.M.

5. OVERBURDEN/WASTE ROCK DISPOSAL:
Sec. 34, 35, T. 74 S., R. 98 E., C.R.M.

WORK: The applicant proposes the construction and operation of a molybdenum mine and ore processing plant with ancillary facilities including a marine terminal, personnel housing, access roads, drainage control structures, water supply facilities, tailings outfall, tailings discharged in marine waters, and overburden/waste rock disposal in waters of the United States. Construction would occur over a five (5) year period and the first two (2) years of mine operation would be concurrent with the fourth and fifth years of the requested five (5) year DA permit. Certain operational discharges requiring DA authorization would be included in the requested DA permit, if permitted. Authorization for continued operational discharges (discharge of mine tailings) for the life of the project would be expected to be reviewed and considered for approval by the Corps every five (5) years as an extension and/or modification to the initial DA permit for construction and operation.

A. Transportation and Utility Systems:

1. MARINE TERMINAL: The marine terminal would occupy approximately 10 acres along approximately 2,500' of the shoreline, generally landward of the existing high tide (HTL), and would chiefly include various open pile and floating structures, proposed waterward of the mean high water mark, with some material discharged below the HTL.

Approximately 105 cubic yards (cy) of gravel fill would be placed below the HTL as a base for the proposed 30'x190' precast concrete boat ramp; and approximately 12,000 cy of rock fill would be placed below the HTL at the existing tideland facility for the construction of a construction barge berth measuring 280'x80'. An additional 1,400 cy of fill (with 800 cy below the HTL) is proposed to be contained by a proposed 100' wide bulkhead with a 20' high face to be constructed at the southward end of the proposed construction barge berth. The berth, bulkhead and fill would be used for rolling off major plant modules weighing up to 1,600 tons.

A temporary floating camp 250'x80' is proposed to be moored eastward of the existing facilities.

Five (5) 9.5'x5' mooring buoys are proposed to be placed north of the proposed marine terminal to accommodate a 35,000 DWT tanker. Proposed submarine oil lines from a marker buoy to oil lines anchored to the seabed floor, would connect the tanker to the terminal.

A 60'x220' open pile wharf, with two (2) approaches 3' wide each, is proposed for shipping and receiving materials. A floating dock 250'x20' with a 120' long ramp is proposed to be constructed parallel to the shoreline for crew boats and would be connected to the shore by a 165'x15' trestle with light vehicle roadway and personnel walkway. This trestle would also carry the treated wastewater effluent pipeline which would discharge at approximately 20' below mean lower low water (MLLW). The proposed marine terminal would also include a floating marina composed of four (4) finger piers (32'x3.5') attached to shore by a dock 8' wide and approximately 90' long.

2. ACCESS ROADS: The existing mine access road is proposed to be widened and other access roads are proposed to be built to the plant and water supply reservoir, and to the Blossom River water intake and pumping station. A 36' wide (surface width) access road is proposed to be built from the proposed marine terminal to the proposed Tunnel Creek concentrator plant site. A 70' cleared width would be needed to transport preassembled modules to the plant site. The alignment would follow the existing road from the south side of Tunnel Creek. There would be two (2) proposed crossings of Tunnel Creek, a 32' crossing (surface width) to the proposed plant and 14' wide crossing (surface width) to the employee housing. The proposed fill material would include 5,000 cy on tidelands of Wilson Arm and 30,000 cy below the OHW of Tunnel Creek and would be composed of clean shot rock.

A permanent mine access road is proposed to be built by expanding the existing 14' wide road to a proposed 28' wide (surface widths) road. The expansion would include fill placed over a proposed water supply pipeline. Approximately 45,000 cy of clean shot rock, including 1,500 cy for turnouts, would be placed below the HTL for the proposed expansion from the intersection with the Tunnel Creek access road to the mine service area. No initial upgrading is proposed for stream crossings at No. 3 Creek, No. 1 Creek, Raspberry Creek, Tunnel Creek, and South Tunnel Creek, nor to replace existing log stringer bridges with permanent steel/concrete bridges and culverts.

An undetermined amount of fill (mine overburden or waste rock) would be placed in waters of the United States, including Beaver Creek and its wetlands, for road expansion to a 28' top width in the vicinity of the mine. This portion of the proposed road expansion would be within the disturbed area boundary of the mine (Drawing Sheet 16 of 34). Most waters of the United States including wetlands within the disturbed area: (1) would be ultimately covered by waste rock or mine overburden waste, or (2) would be covered by fill for specific activities.

A 3,000' long, 14' wide (surface width) road is proposed to be constructed from the mine access road to the Blossom River water intake and pumping station. Approximately 5,000 cy of clean shot rock is proposed to be placed in waters of the United States, including wetlands, for the construction of the access road.

3. BLOSSOM RIVER WATER INTAKE: 2,270 cy of bottom material would be excavated below the meam high water (MHW) and 1,350 cy of back fill would be placed below the HTL of the Blossom River to conctruct the proposed water intake. Incidental fill would be utilized for the installation of a filter bed with perforated piping and a series of intake pipes leading to a pumping station located on shore as proposed for water withdrawal from the Blossom River.

4. WATER SUPPLY PIPELINE: A 30 inch diameter pipeline would be constructed from the Blossom River pumping station to the plant site. It would be included within proposed road fills.

5. WATER SUPPLY DAM: A proposed 52' high dam in Tunnel Creek would be the primary source for potable and mill process water. Approximately 330,000 cy of shot rock and alluvial fill would comprise the diversion dike and dam embankment. Included in this amount is approximately 6,000 cy which would be placed below the OHW of Tunnel Creek, in waters of the United States. The reservoir created by the proposed impoundment would be about 35 acres. A pipeline and access road would be constructed to the plant site.

A diversion dam on No. 1 Creek is proposed to be constructed for the mine housing facility water supply. A trench would be excavated across No. 1 Creek and 200 cy of fill, mainly clean shot rock with a glacial fill barrier layer, would be discharged into waters of the United States as a foundation of a weir. Approximately 50 cy would be placed below the OHW and approximately 150 cy would be in adjacent wetlands. The proposed weir or diversion dam would create a 0.1 acre impoundment. The weir would be built by placing concrete into tightly fitted forms.

Three additional diversion dams are proposed. Water from these sources would be used for dust suppression of roads, fire protection, sanitation and potable water requirements for the proposed Wilson Arm Marine Terminal and the proposed Mine Service Facilities. One of the diversion dams would be constructed on the unnamed creek located between the proposed Marine Terminal and the proposed Tunnel Creek Plant Site. The other two diversion dams would be constructed on two unnamed tributaries to Beaver Creek.

The three additional proposed diversion dams would be essentially the same except for magnitude, and similar to the design described for the proposed diversion dam on No. 1 Creek. The water supply diversion dam near the Marine Terminal would require 25 cy of fill below the OHW and would create an impoundment area of approximately 0.1 acre. Each water supply diversion dam

for the Mine Service Facility would require 45 cy of fill below the OHW and would create an impoundment area of approximately 0.2 acre. The proposed diversion dams or weirs would be built by placing concrete into tightly fitted forms.

The discharge of fill material for the two proposed diversion dams of the mine service facility are authorized by regulation [33 CFR 330.5(a)(26)(i)], at the described locations on the tributaries to Beaver Creek. An individual DA permit is required for the discharge of fill material for the proposed diversion dam of the marine facilities, the Tunnel Creek impoundment and the diversion dam on No. 1 Creek.

6. TAILINGS OUTFALL AND ASSOCIATED FACILITIES: Mine tailings from the Tunnel Creek concentrator plant would be transported for discharge into Wilson Arm of Smeaton Bay by proposed pipelines on a raised berm adjacent to the plant access road through a series of drop boxes to the marine terminal. The tailings would be cased in 36 inch diameter pipes for transport around the terminal, then through a mixing chamber and a submarine pipeline which is proposed to discharge at -150' MLLW. Facilities which would require DA authorization through the Corps, in the area of the outfall, includes the following work and structures proposed to be constructed in waters of the United States: an access foot bridge, drop box and mixing chamber, a dredged cut and tailings discharge pipeline.

The proposed submarine tailings pipeline would be approximately 1,000' long and included a double "dog-legged" 48 inch diameter discharge line and two (2) 24 inch diameter by approximately 300' long water intake pipes. A proposed 150' long bridge would support and connect the pipeline on the shore to the mixing chamber/drop box and submarine portion of the pipeline. The waterward end of the foot bridge, the mixing chamber/drop box and origins of the submarine pipeline would be located in a proposed triangular - wedge cut. The proposed cut would involve removing 1,700 cy rock with a clamshell dredge. The dredged material would be used to fill the proposed construction barge berth pad.

B. Other Facilities:

1. SEDIMENT CONTROL DAMS: Mining would entail removal and disposal of overburden, including wetlands (muskeg type), so that ore can be removed and transported to the crusher. The mining activity would eventually cover portions of Upper Beaver Creek, White Creek, and Hill Creek including wetlands. The disposal of these wastes (i.e., overburden/waste rock) in waters of the United States are under Corps' regulatory jurisdiction. The proposed sediment control dams on these waters require DA authorization and they would control water runoff from the waste rock piles. A dam would be constructed in Hill Creek and one in White Creek, and two (2) dams would be constructed in Beaver Creek. The proposed sediment control dams would be composed of select glacial fill, processed sand and gravel and select rock from mine waste. The proposed Hill Creek embankment for the dam would include 3,600,000 cy of fill with 25,000 cy below the OHW. The proposed White Creek

dam's embankment would include 850,000 cy of fill with 10,000 cy below the OHW. The proposed Upper Beaver Creek dam's embankment would include 310,000 cy of fill with 5,000 cy below the OHW. The proposed Lower Beaver Creek dam's embankment would include 1,400,000 cy of fill with 14,000 cy below the OHW.

2. MINE PERSONNEL HOUSING: A personnel housing facility is proposed to be built on a fill within the boundary of the disturbed area and in wetlands of No. 1 Creek, about one (1) mile northwest of the mine service area. The proposed fill would consist of an excavated level pad, composed of 9,000 cy of rock fill, with housing structures, a mess hall, recreational facility and sewage treatment plant.

3. MINE SERVICE FACILITY: The proposed mine service area would be built in the mine area near the head of Beaver Creek. It would consist of a level pad, composed of 1,000,000 cy of rock fill of which 500,000 cy would be on wetlands, with a maintenance building, storage area, truck parking area, fuel tanks and fuel dispensing facilities. A pad would also be proposed for storage and handling of blasting agents. The proposed pads would be located within the boundary of disturbed area.

4. TAILING DISPOSAL: The proposed five (5) year DA permit would also authorize the first two (2) years of mine operation that would include 21,000,000 cy of tailing discharged into navigable waters of the United States and require authorization for the Corps of Engineers under Section 10 of the Rivers and Harbors Act of 1899, as well as the Environmental Protection Agency's authorization under the Clean Water Act. The remaining 52 years of the mine operation would be require an additional 1,110,000,000 cy of tailing discharged into Wilson Arm of Smeaton Bay. Every five (5) years the DA permit would be expected to be extended or modified by the Corps upon review of the project and the NPDES action of EPA, if the initial permits are approved.

5. OVERBURDEN/WASTE ROCK DISPOSAL: During the first two (2) years of mine operation, coinciding with years four (4) and five (5) of mine construction, overburden/waste rock would be discharged in waters or wetlands of Beaver Creek. The overburden/waste rock would include 370,000 cy of muskeg (plants, with underlying organic and mineral soils), 610,000 cy of glacial till and 11,200,000 cy of waste rock. No additional overburden/waste rock discharges are expected during the remaining period of mine operation.

PURPOSE: The purpose is to construct the described transportation and utility systems, along with mine service and housing facilities, and sediment control dams, for the development and operation of a proposed molybdenum mine, the Quartz Hill Molybdenum Project.

ADDITIONAL INFORMATION: The U.S. Forest Service is preparing an EIS for the Quartz Hill Molybdenum Project, including components which require authorization from the Corps of Engineers. The Alaska District Corps of Engineers is a cooperating agency in the EIS. A permit decision regarding the components needing DA approval will not be made until after the EPA authorizes the discharge of effluent from the proposed sediment control dams and the proposed discharge of mine tailings under the requirements of Section 402 of the Clean

Water Act and the final EIS has been reviewed. This public notice reflects the applicant's preferred alternative. Other alternatives are being considered in the EIS process and a discussion of these alternatives can be found in Section 2 of the EIS.

AUTHORITY: This permit will be issued or denied under the following authorities:

(X) Perform work in or affecting navigable waters of the United States - Section 10 Rivers and Harbors Act 1899 (33 U.S.C. 403).

(X) Discharge dredged or fill material into waters of the United States - Section 404 Clean Water Act (33 U.S.C. 1344).

WATER QUALITY CERTIFICATION: A permit for the described work will not be issued until a certification or waiver of certification, as required under Section 401 of the Clean Water Act (Public Law 95-217), has been received from the Alaska Department of Environmental Conservation.

COASTAL ZONE MANAGEMENT ACT CERTIFICATION: Section 307(c)(3) of the Coastal Zone Management Act of 1972, as amended by 16 U.S.C. 1456(c)(3), requires the applicant to certify that the described activity affecting land or water uses in the Coastal Zone complies with the Alaska Coastal Management Program. A permit will not be issued until the Office of Management and Budget, Division of Governmental Coordination has concurred with the applicant's certification. This certification review will begin with a separate Public Notice to be issued by the State of Alaska at a later date.

PUBLIC HEARING: The Corps of Engineers, the Forest Service and the U.S. Environmental Protection Agency may hold a joint public hearing to receive comments and give the public an opportunity to express their views on the adequacy of the final EIS. If a public hearing is held it will be in Ketchikan, Alaska at a time, date and location to announced to interested parties at least 30 days prior to the public hearing. Regulations do not require that a public hearing be held for the final EIS. A public hearing was held, as required, during the review of draft EIS on September 6, 1984.

CULTURAL RESOURCES: The latest published version of the National Register of Historic Places has been consulted and no properties listed on or known to be eligible for inclusion on the Register are located in the permit area.

ENDANGERED SPECIES: Preliminarily, the described activity will not affect endangered species, or their critical habitat designated as endangered or threatened, under the Endangered Species Act of 1973 (87 Stat. 844). Formal consultation under Section 7 of the Act is not required for the described activity.

FEDERAL SPECIES OF CONCERN: The following Federal species of concern are discussed in the final EIS and use the project area: Steelhead Trout, Sockeye Salmon, Chinook Salmon, Coho Salmon, Canada Goose, Bald Eagle, Trumpeter Swan, Tundra (Whistling) Swan, and Mallard. The following Federal species may use the project area: Canvasback, Lesser Sandhill Crane and Peale's Peregrine Falcon.

FLOOD PLAIN MANAGEMENT: Evaluation of the described activity will include conformance with appropriate State or local flood plain standards; consideration of alternative sites and methods of accomplishment; and weighing of the positive, concentrated and dispersed, and short and long-term impacts on the flood plain.

EVALUATION: The decision whether to issue a permit will be based on an evaluation of the probable impacts including cumulative impacts of the proposed activity on the public interest. Evaluation of the probable impacts which the proposed activity may have on the public interest requires a careful weighing of all those factors which become relevant in each particular case. The benefits which reasonably may be expected to accrue from the proposal must be balanced against its reasonably foreseeable detriments. The decision whether to authorize a proposal, and if so the conditions under which it will be allowed to occur, are therefore determined by the outcome of the general balancing process. That decision should reflect the national concern for both protection and utilization of important resources. All factors which may be relevant to the proposal must be considered including the cumulative effects thereof. Among those are conservation, economics, aesthetics, general environmental concerns, wetlands, cultural values, fish and wildlife values, flood hazards, floodplain values, land use, navigation, shore erosion and accretion, recreation, water supply and conservation, water quality, energy needs, safety, food and fiber production, mineral needs, considerations of property ownership, and, in general, the needs and welfare of the people. For activities involving 404 discharges, a permit will be denied if the discharge that would be authorized by such permit would not comply with the EPA's 404(b)(1) guidelines. Subject to the preceding sentence and any other applicable guidelines or criteria (see Sections 320.2 and 320.3), a permit will be granted unless the District Engineer determines that it would be contrary to the public interest.

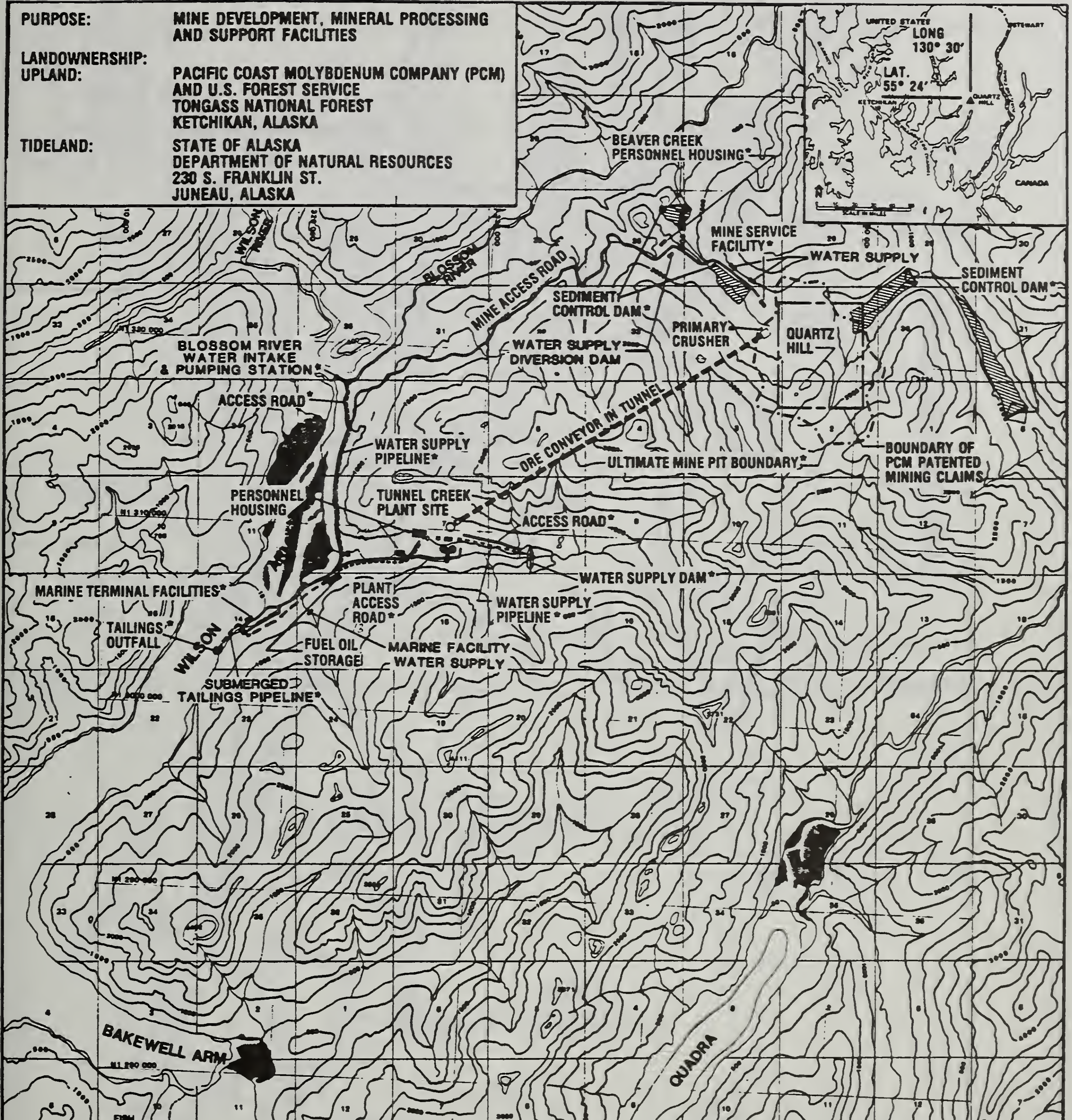
All comments submitted should cite the reference number, 2-840015, for this project. Public comments will be received by the Corps after publication of the final EIS. Final comments should reach this office no later than 30 days after the publication of the notice of availability of the final EIS, or the expiration date of this notice (which ever is later), to become part of the record and be considered in the permit decision. Please address your comments to U.S. Army Corps of Engineers, Alaska District, Regulatory Branch, ATTN: Gene V. Augustine, Post Office 898, Anchorage, Alaska 99506-0898. Copies of any

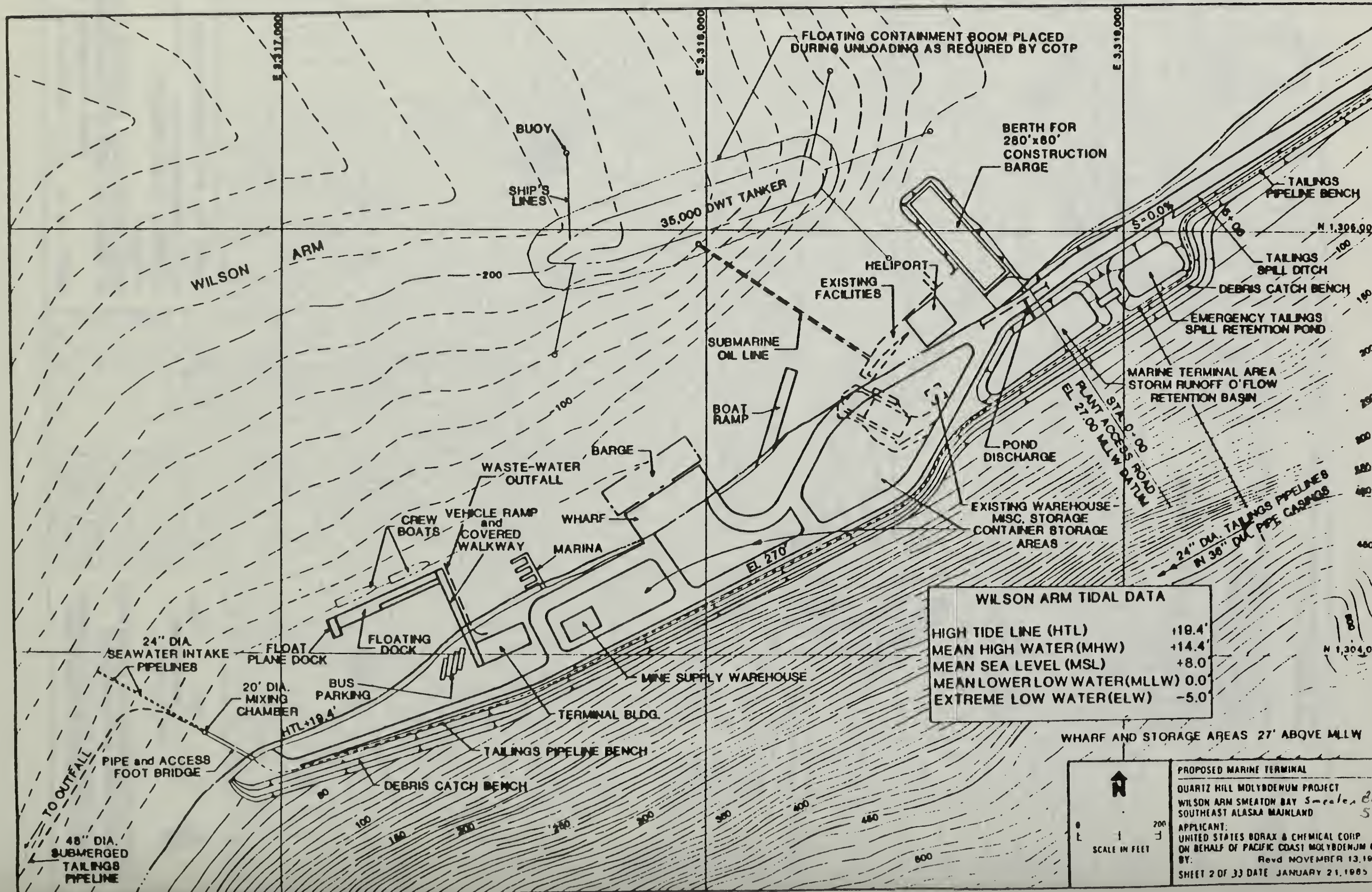
comments should be sent to Mr. J. Michael Lunn, U.S.D.A. Forest Service, Tongass National Forest, Federal Building, Ketchikan, Alaska 99901. If further information is desired concerning this notice, contact Mr. Augustine, Special Actions Section of the Regulatory Branch at (907) 753-2724.

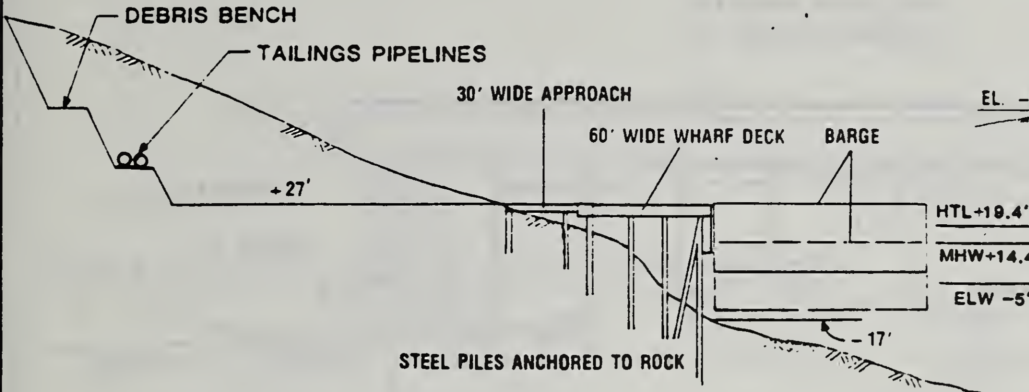
A Plan and Notice of Application for State Water Quality Certification are attached to this Public Notice.

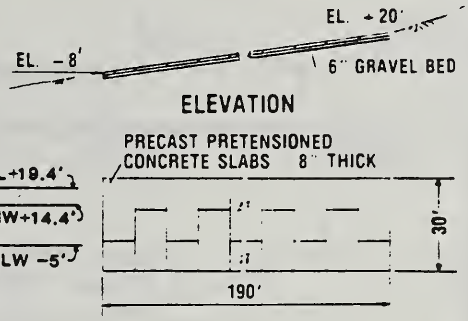
District Engineer
U.S. Army, Corps of Engineers

Attachments


PURPOSE: MINE DEVELOPMENT, MINERAL PROCESSING AND SUPPORT FACILITIES
LANDOWNERSHIP:
UPLAND: PACIFIC COAST MOLYBDENUM COMPANY (PCM) AND U.S. FOREST SERVICE TONGASS NATIONAL FOREST KETCHIKAN, ALASKA
TIDELAND: STATE OF ALASKA DEPARTMENT OF NATURAL RESOURCES 230 S. FRANKLIN ST. JUNEAU, ALASKA
UNITED STATES
LONG 130° 30'
LAT. 55° 24'
KETCHIKAN
QUARTZ HILL
CANADA
BEAVER CREEK PERSONNEL HOUSING*
MINE SERVICE FACILITY*
WATER SUPPLY
SEDIMENT CONTROL DAM*
BLOSSOM RIVER
MINE ACCESS ROAD
SEDIMENT CONTROL DAM*
PRIMARY CRUSHER
QUARTZ HILL
WATER SUPPLY DIVERSION DAM
BLOSSOM RIVER WATER INTAKE & PUMPING STATION*
ACCESS ROAD*
ORE CONVEYOR IN TUNNEL
WATER SUPPLY PIPELINE*
ULTIMATE MINE PIT BOUNDARY*
BOUNDARY OF PCM PATENTED MINING CLAIMS
PERSONNEL HOUSING
TUNNEL CREEK PLANT SITE
ACCESS ROAD*
WATER SUPPLY DAM*
MARINE TERMINAL FACILITIES*
PLANT ACCESS ROAD*
WATER SUPPLY PIPELINE*
TAILINGS OUTFALL
FUEL OIL STORAGE
MARINE FACILITY WATER SUPPLY
WILSON
SUBMERGED TAILINGS PIPELINE*
BAKEWELL ARM
FISH LADDER
CABIN
QUADRA
DE
BOCA
SILL
N
0 5000 10000
SCALE IN FEET
DATUM: MEAN LOWER LOW WATER FROM USGS KETCHIKAN B-2 QUADRANGLE
* ALL OR A PORTION OF THESE PROJECT FACILITIES REQUIRE A DEPARTMENT OF THE ARMY PERMIT
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
Smeaton Bay 5
SOUTHEAST ALASKA MAINLAND
APPLICANT:
UNITED STATES BORAX & CHEMICAL CORP. ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13,1987
SHEET 1 OF 33 DATE: JANUARY 21,1985

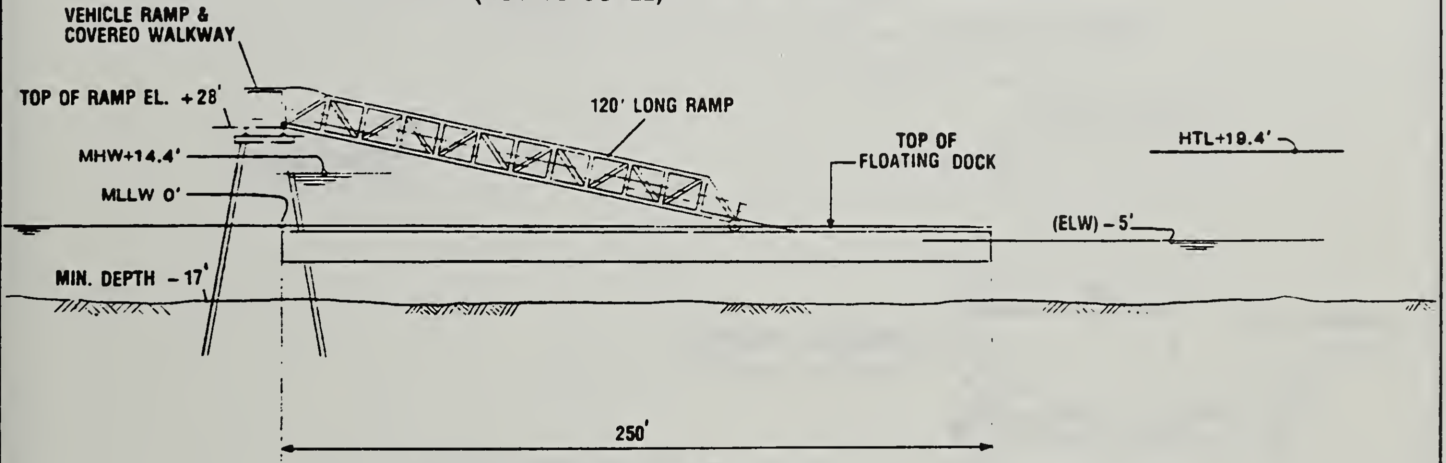

FLOATING CONTAINMENT BOOM PLACED DURING UNLOADING AS REQUIRED BY COTP
BERTH FOR 260'x60' CONSTRUCTION BARGE
BUOY
SHIP'S LINES
35,000 DWT TANKER
WILSON ARM
HELIPORT
EXISTING FACILITIES
SUBMARINE OIL LINE
BOAT RAMP
BARGE
WASTE-WATER OUTFALL
VEHICLE RAMP and COVERED WALKWAY
WHARF
MARINA
CREW BOATS
FLOATING DOCK
FLOAT PLANE DOCK
24" DIA. SEAWATER INTAKE PIPELINES
20' DIA. MIXING CHAMBER
BUS PARKING
HTL+19.4'
PIPE and ACCESS FOOT BRIDGE
TO OUTFALL
48" DIA. SUBMERGED TAILINGS PIPELINE
DEBRIS CATCH BENCH
TAILINGS PIPELINE BENCH
TERMINAL BLDG.
MINE SUPPLY WAREHOUSE
EL 270'
EXISTING WAREHOUSE - MISC. STORAGE CONTAINER STORAGE AREAS
POND DISCHARGE
STA 0+00 PLANT ACCESS ROAD EL 27.00 MLLW DATUM
MARINE TERMINAL AREA STORM RUNOFF O'FLOW RETENTION BASIN
EMERGENCY TAILINGS SPILL RETENTION POND
DEBRIS CATCH BENCH
TAILINGS SPILL DITCH
TAILINGS PIPELINE BENCH
S=0.0%
24" DIA. TAILINGS PIPELINES IN 36" DIA. PIPE CASINGS
E 3,317,000
E 3,318,000
E 3,319,000
N 1,305,000
N 1,304,000
WILSON ARM TIDAL DATA
HIGH TIDE LINE (HTL) +19.4'
MEAN HIGH WATER (MHW) +14.4'
MEAN SEA LEVEL (MSL) +8.0'
MEAN LOWER LOW WATER (MLLW) 0.0'
EXTREME LOW WATER (ELW) -5.0'
WHARF AND STORAGE AREAS 27' ABOVE MLLW
SCALE IN FEET
PROPOSED MARINE TERMINAL
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM SMEATON BAY
SOUTHEAST ALASKA MAINLAND
APPLICANT:
UNITED STATES BORAX & CHEMICAL CORP
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO
BY: Revd NOVEMBER 13,1987
SHEET 2 OF 33 DATE JANUARY 21,1985





BOAT RAMP DETAIL
(NOT TO SCALE)

BARGE WHARF DETAIL
(NOT TO SCALE)



ELEVATION AT FLOATING DOCK
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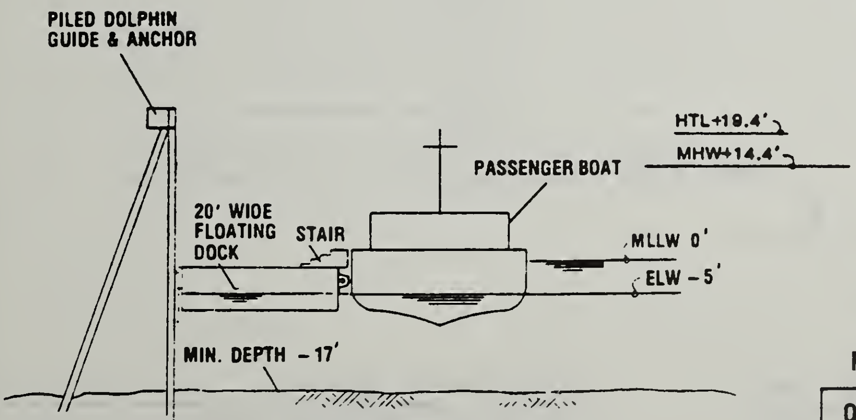
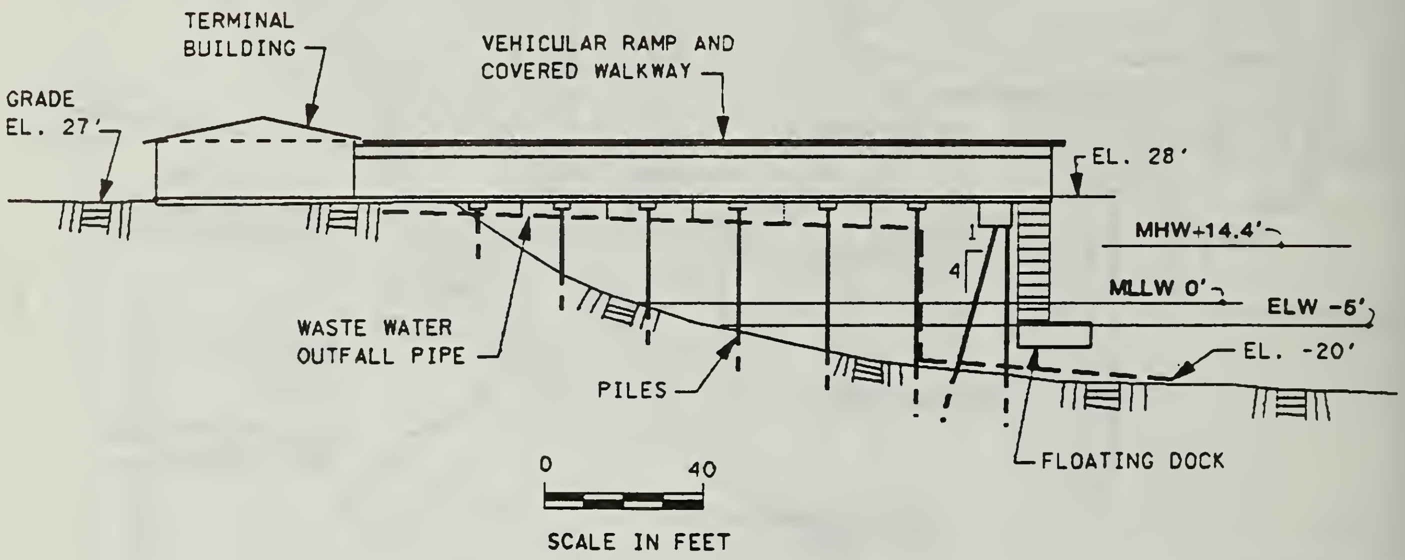
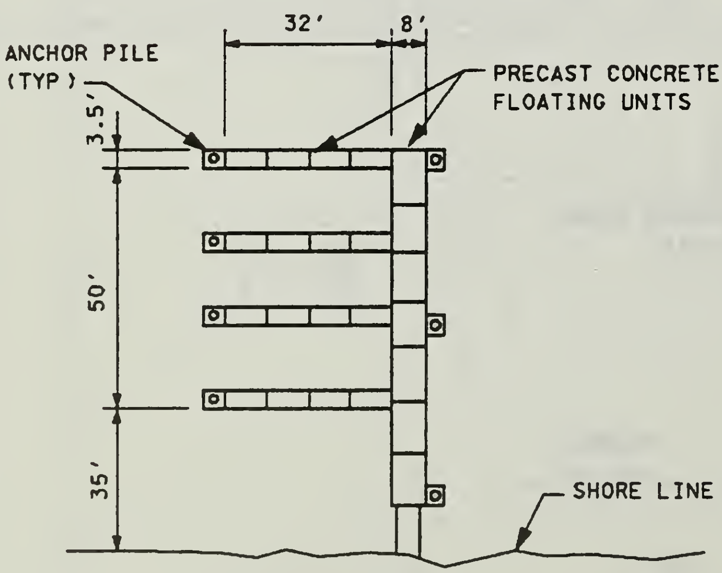


SECTION AT FLOATING DOCK
(NOT TO SCALE)

PROPOSED MARINE TERMINAL

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY Smeaton Bay 5
SOUTHEAST ALASKA MAINLAND
APPLICANT:
UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13,1987
SHEET 3 OF 33 DATE: JANUARY 21,1985





MARINA DETAIL

0 50

SCALE IN FEET

PROPOSED MARINE TERMINAL

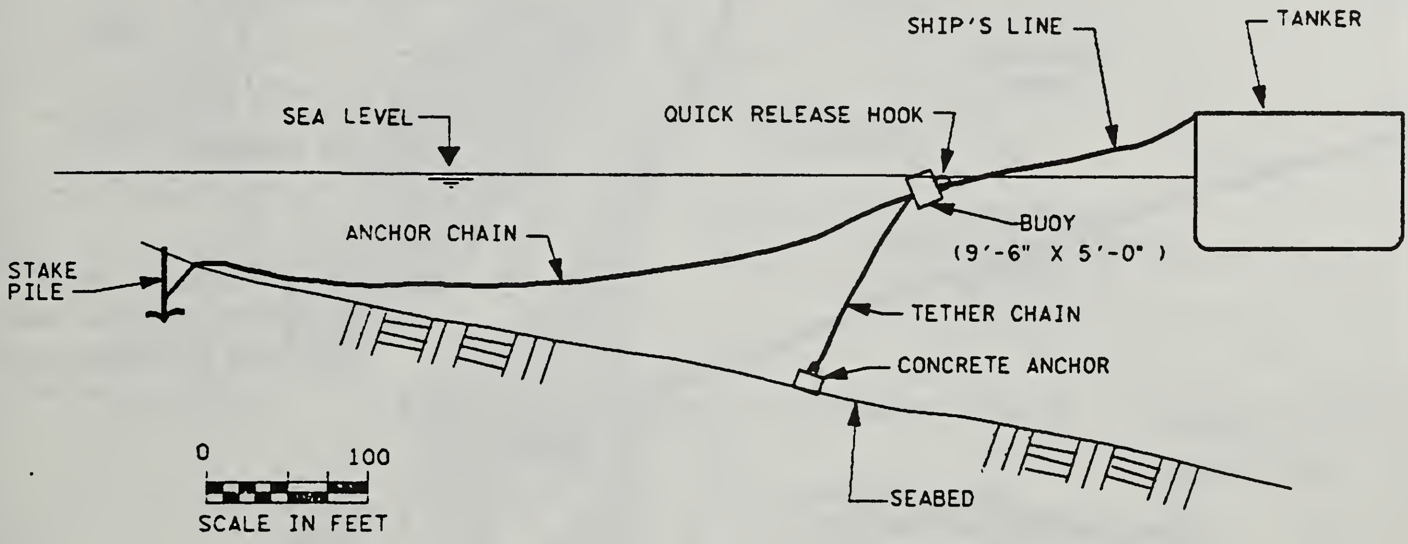
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND

Smeaton Bay 5

APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

Revd. NOVEMBER 13,1987

SHEET 4 OF 33 DATE: JANUARY 21,1985



POINT N°*	5 POINT MOORING ANCHOR CHAIN LENGTH
1	480 FT
2	1500 FT
3	420 FT
4	240 FT
5	200 FT

* SEE SHEET 2 FOR MOORING PLAN

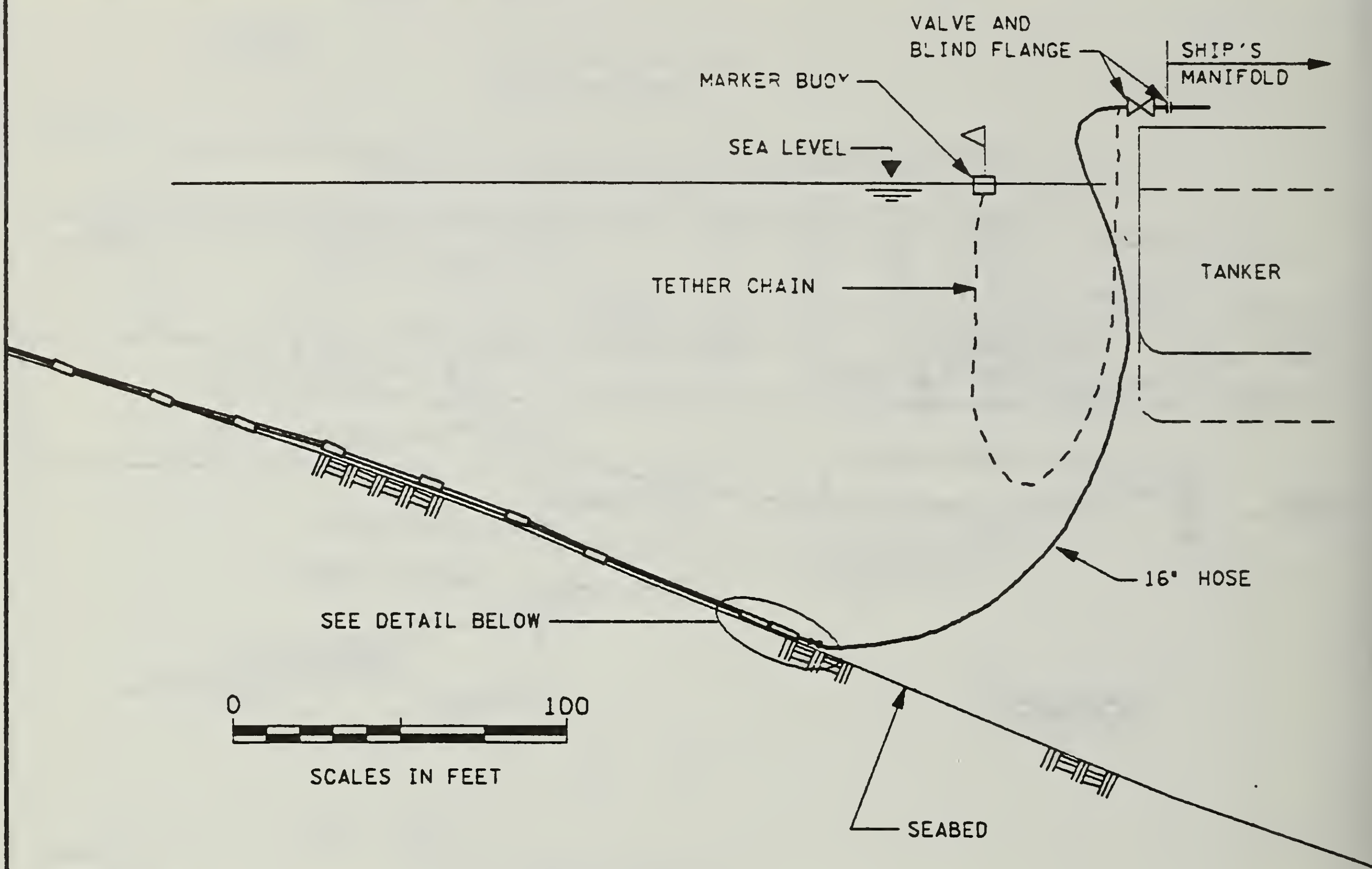
TANKER MOORING DETAILS

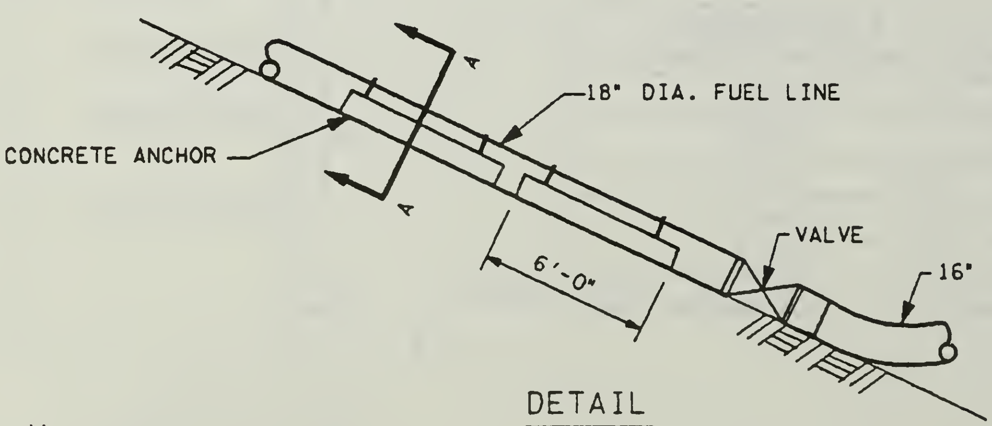
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND

Smeaton Bay 5

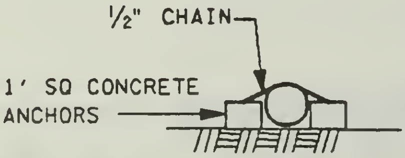
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

Revd. NOVEMBER 13,1987
SHEET 5 OF 33 DATE: JANUARY 21,1985





DETAIL

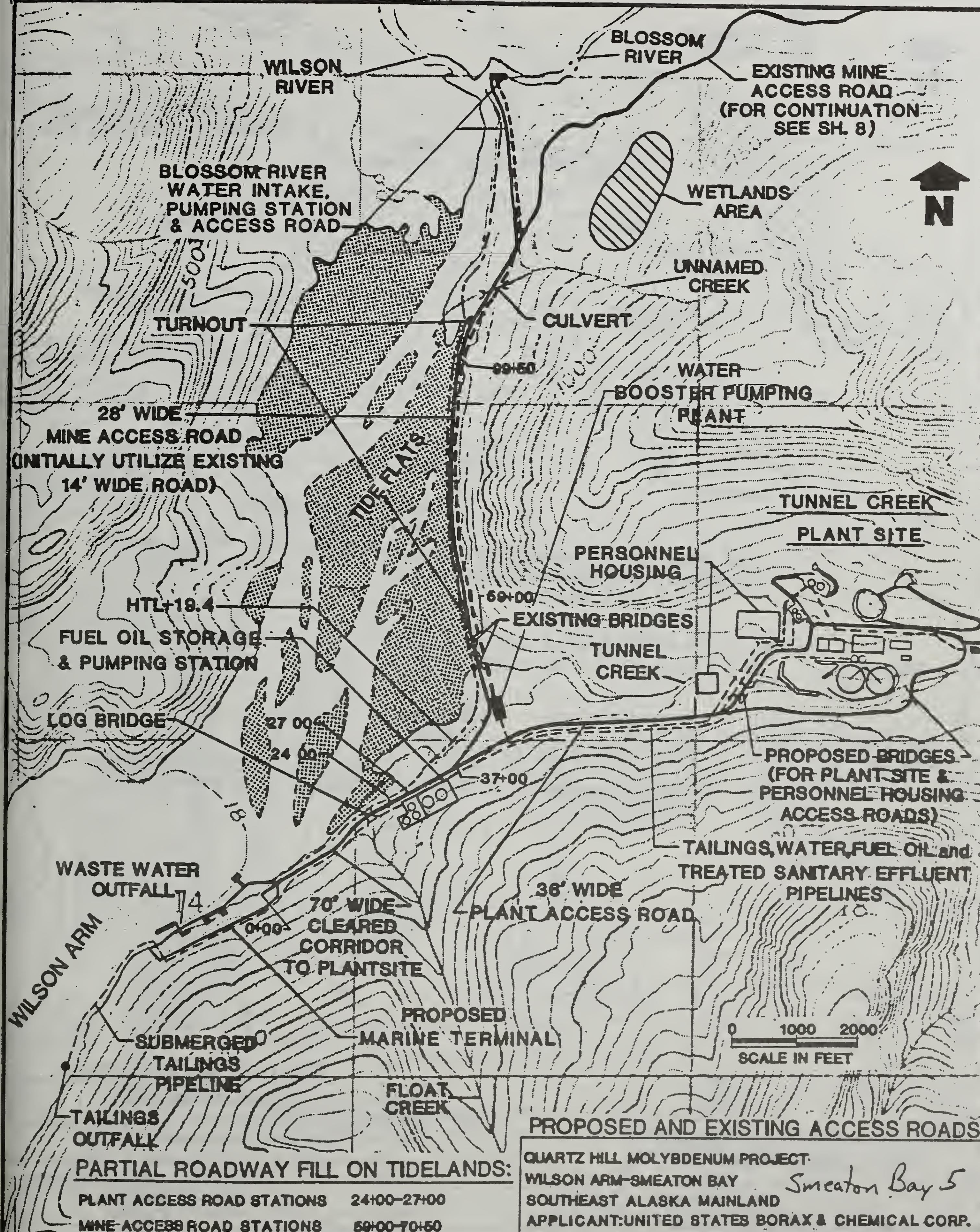


SECTION A-A

NOTE:
DETAILS OF DIESEL OIL LINE (8" DIA PIPE, 6" DIA HOSE) ARE NOT SHOWN BUT ARE SIMILAR TO ABOVE FUEL OIL LINE DETAILS.

SUBMARINE OIL LINES

QUARTZ HILL MOLYBDENUM PROJECT WILSON ARM-SMEATON BAY SOUTHEAST ALASKA MAINLAND	Smeaton Bay 5
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP. ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.	
SHEET 6 OF 33	Revd. NOVEMBER 13,1987 DATE: JANUARY 21,1985

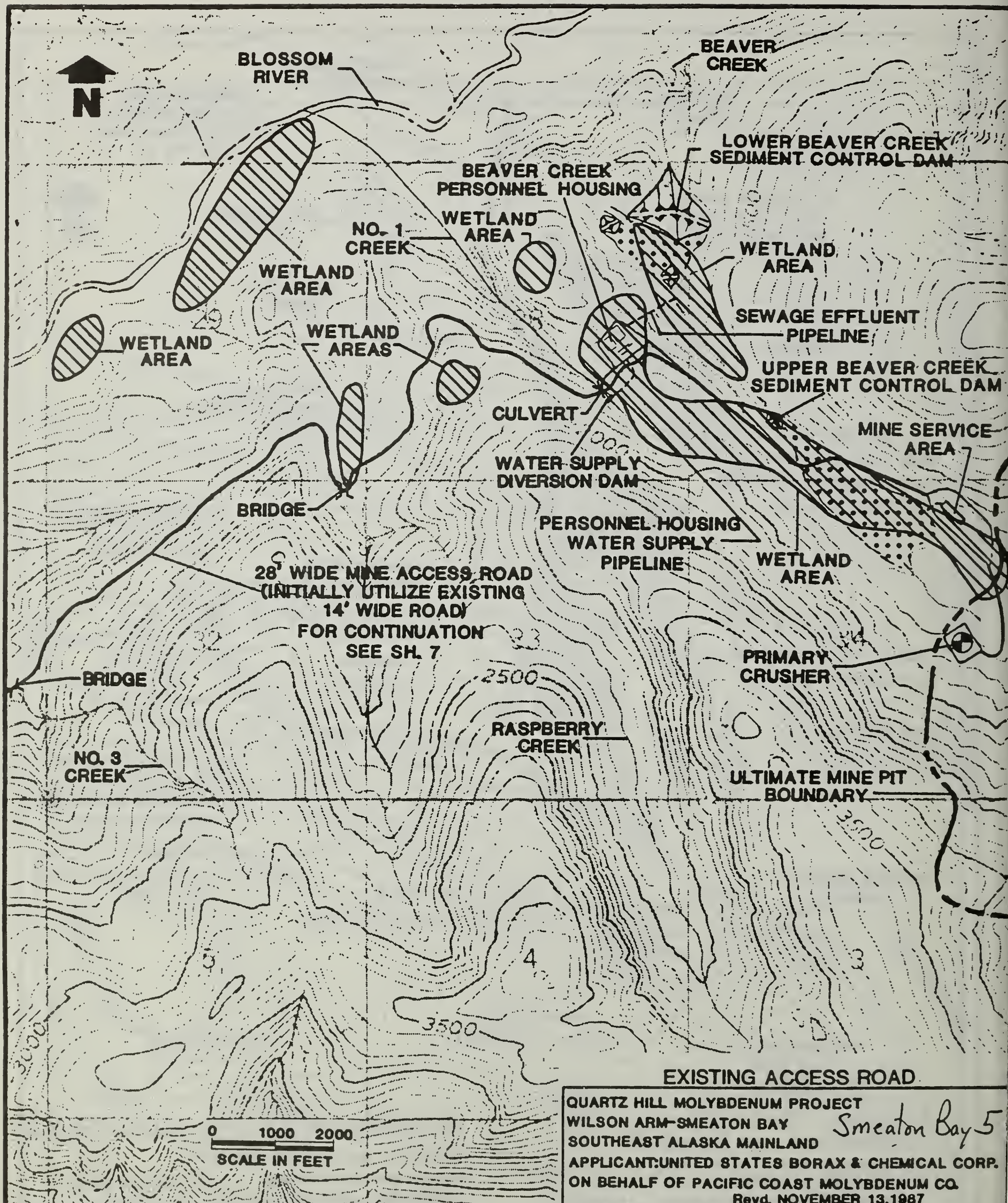


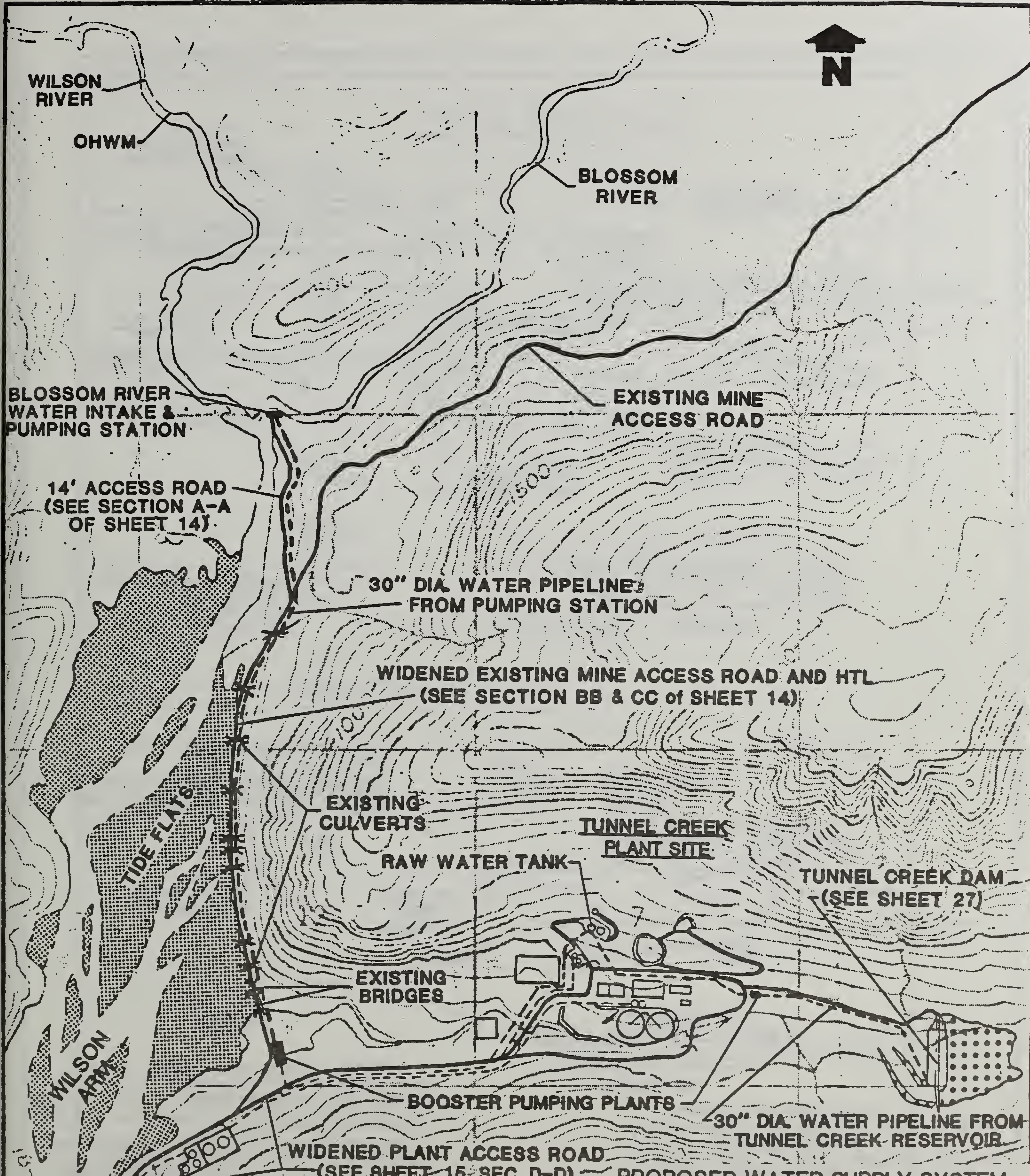
PARTIAL ROADWAY FILL ON TIDELANDS:

PLANT ACCESS ROAD STATIONS	24+00–27+00
MINE ACCESS ROAD STATIONS	59+00–70+50
	73+00–83+50
	85+50–95+00
	98+00–99+50

PROPOSED AND EXISTING ACCESS ROADS

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY Smeaton Bay 5
SOUTHEAST ALASKA MAINLAND
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13, 1987
SHEET 7 of 33 DATE: JANUARY 21, 1985


N
BLOSSOM RIVER
BEAVER CREEK
LOWER BEAVER CREEK SEDIMENT CONTROL DAM
BEAVER CREEK PERSONNEL HOUSING
WETLAND AREA
NO. 1 CREEK
WETLAND AREA
WETLAND AREA
WETLAND AREA
WETLAND AREAS
SEWAGE EFFLUENT PIPELINE
UPPER BEAVER CREEK SEDIMENT CONTROL DAM
CULVERT
MINE SERVICE AREA
WATER SUPPLY DIVERSION DAM
BRIDGE
PERSONNEL HOUSING WATER SUPPLY PIPELINE
WETLAND AREA
28' WIDE MINE ACCESS ROAD (INITIALLY UTILIZE EXISTING 14' WIDE ROAD)
FOR CONTINUATION SEE SH. 7
PRIMARY CRUSHER
BRIDGE
2500
RASPBERRY CREEK
NO. 3 CREEK
ULTIMATE MINE PIT BOUNDARY
3500
3500
3000
0 1000 2000
SCALE IN FEET
EXISTING ACCESS ROAD
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND
Smeaton Bay 5
APPLICANT:UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13,1987
SHEET 8 of 33 DATE: JANUARY 21,1985



PROPOSED WATER SUPPLY SYSTEM-PIPELINES & ACCESS ROAD

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND
APPLICANT:UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
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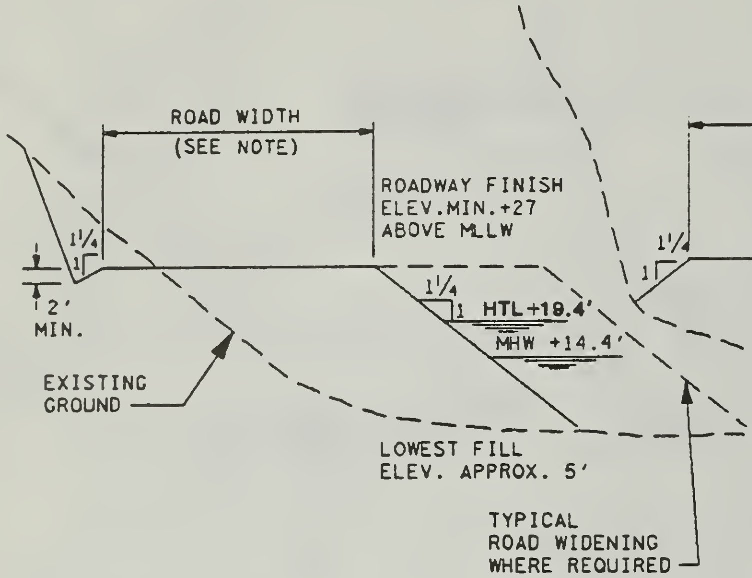
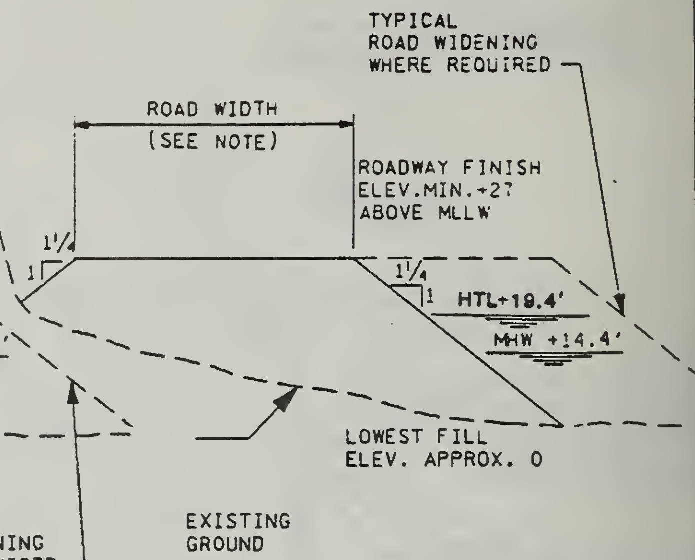
Smeaton Bay 5





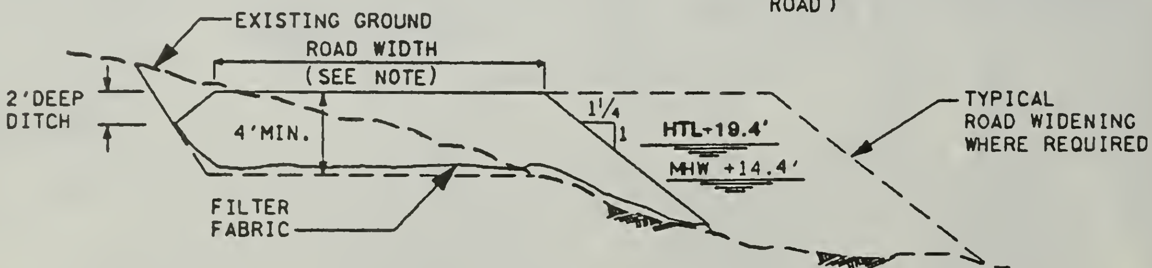
TYPICAL ROADWAY SECTION
PARTIALLY ON TIDELANDS

NOT TO SCALE

TYPICAL ROADWAY SECTION
ON TIDELANDS

NOT TO SCALE

NOTE: PLANT ACCESS ROAD WIDTH APPROX. 36'.
MINE ACCESS ROAD WIDTH APPROX. 28'
(INITIALLY UTILIZE EXISTING 14' WIDE ROAD)



TYPICAL ROADWAY SECTION
IN WETLAND AREAS

NOT TO SCALE

PROPOSED ACCESS ROAD TYPICAL DETAILS

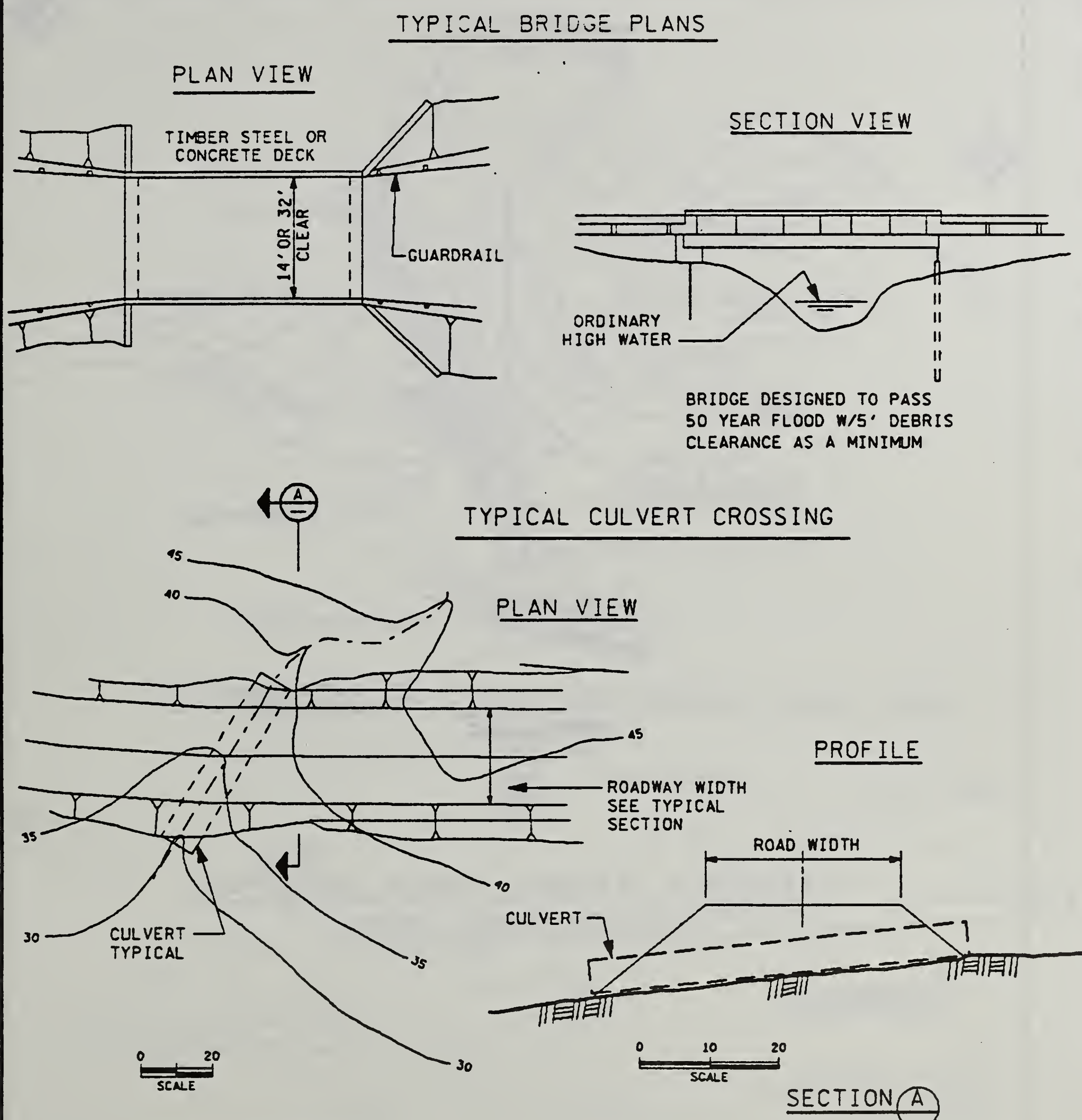
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND

Smeaton Bay 5

APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

Revd. NOVEMBER 13,1987

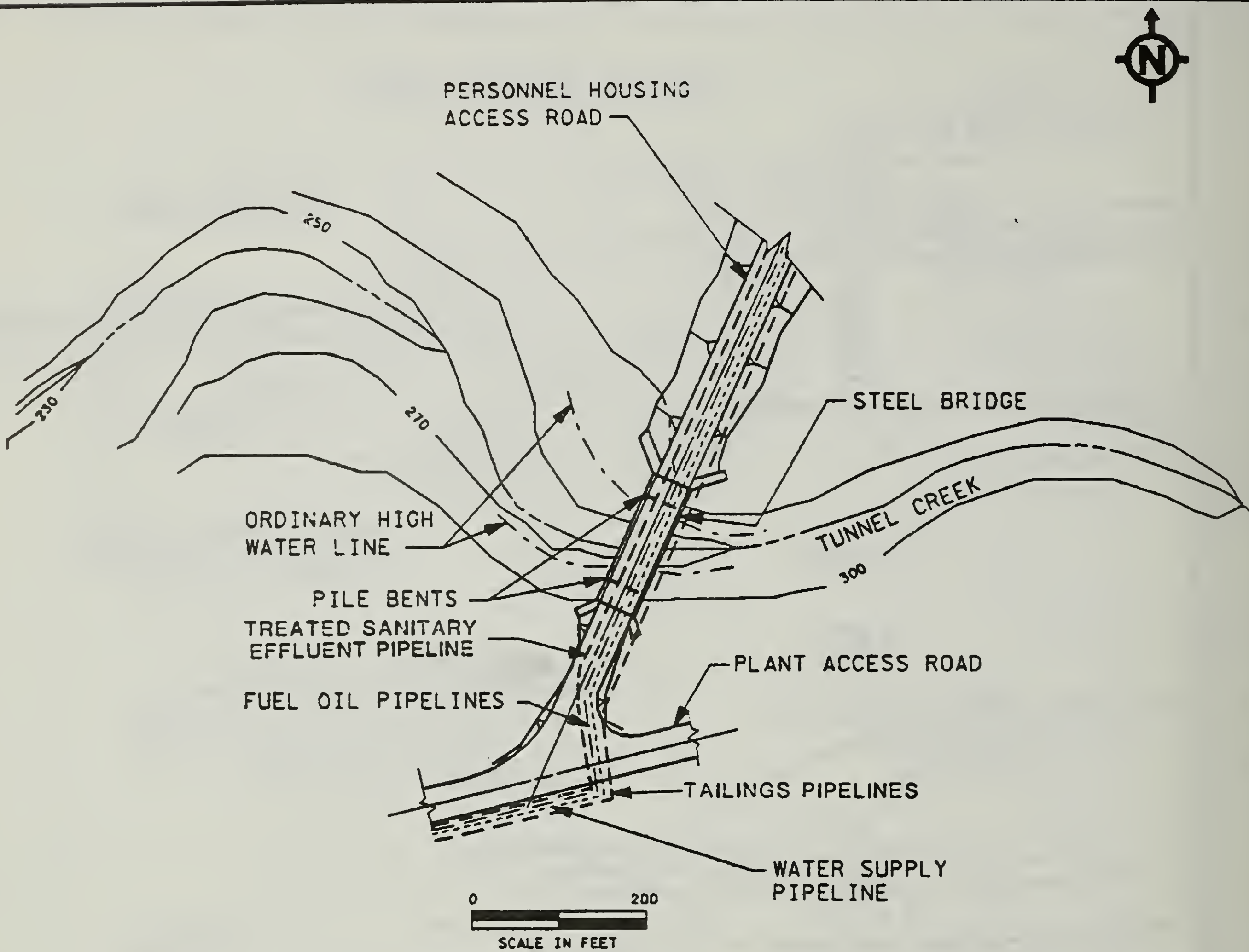
SHEET 10 OF 33 DATE: JANUARY 21,1985



PROPOSED ACCESS ROAD DETAILS

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND Smeaton Bay 5

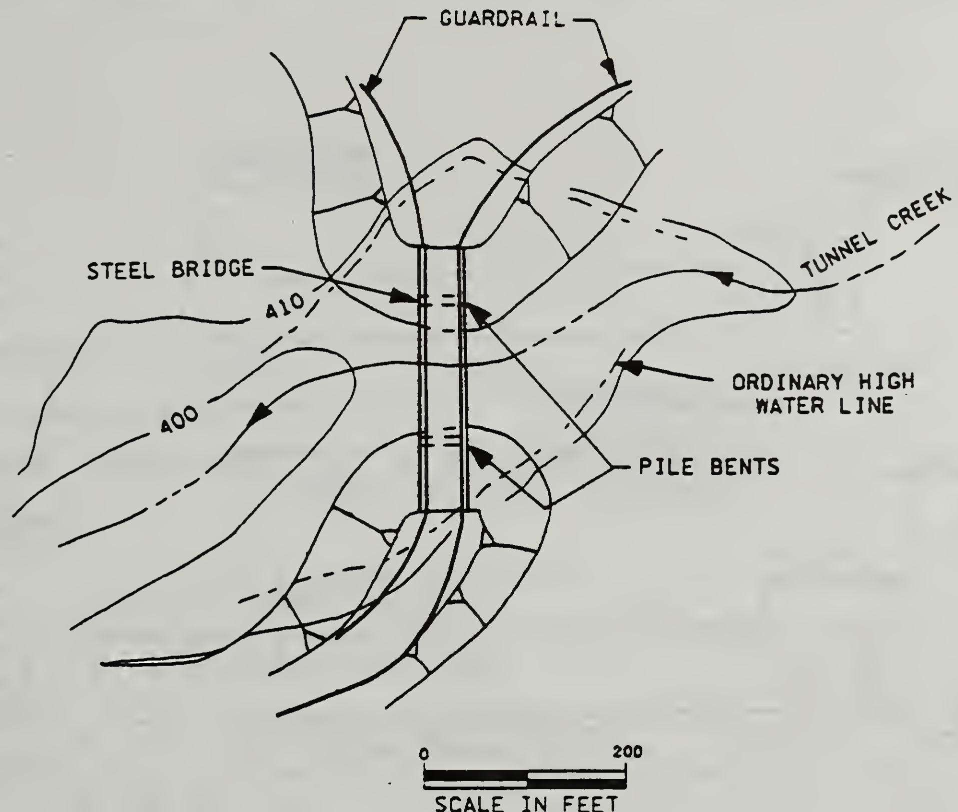
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13,1987
SHEET 11 OF 33 DATE: JANUARY 21,1985



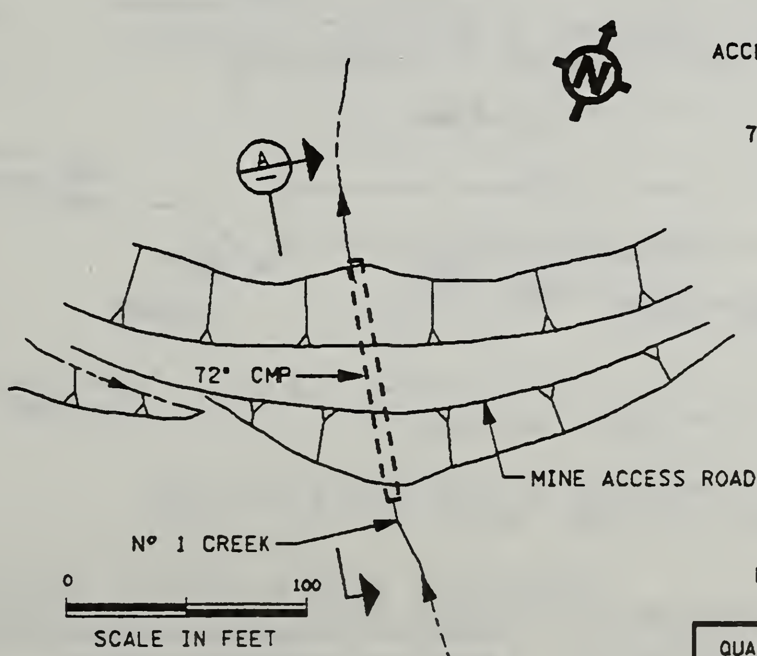
PLAN VIEW OF PERSONNEL HOUSING ACCESS ROAD CROSSING TUNNEL CREEK

PROPOSED ACCESS ROAD

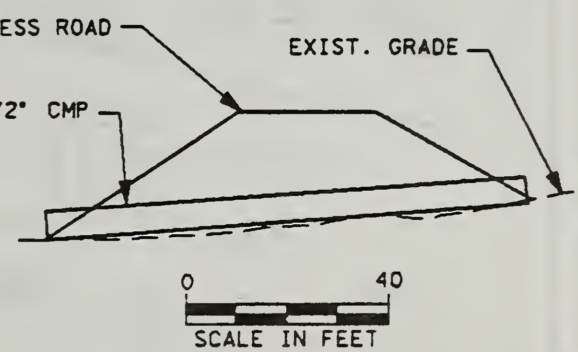
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY Smeaton Bay 5
SOUTHEAST ALASKA MAINLAND
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13,1987
SHEET 12 OF 33 DATE: JANUARY 21,1985



PLAN VIEW OF PLANT ACCESS ROAD CROSSING TUNNEL CREEK



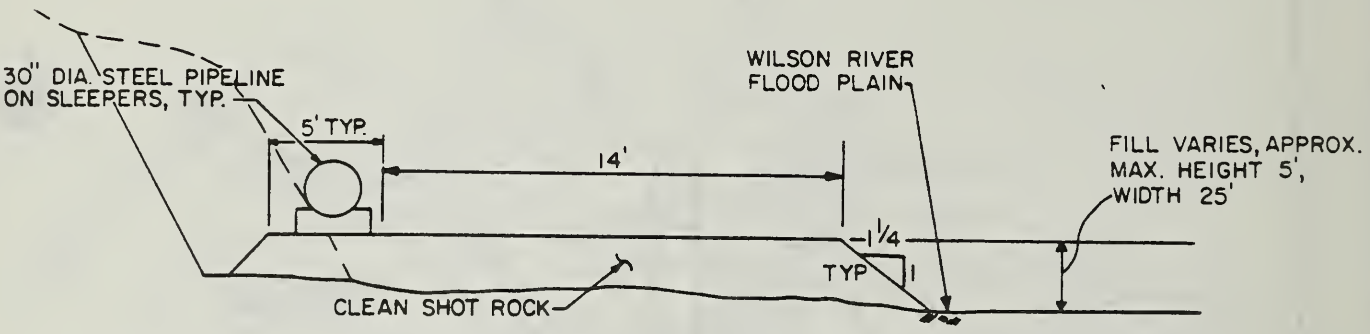
NO. 1 CREEK ROAD CROSSING



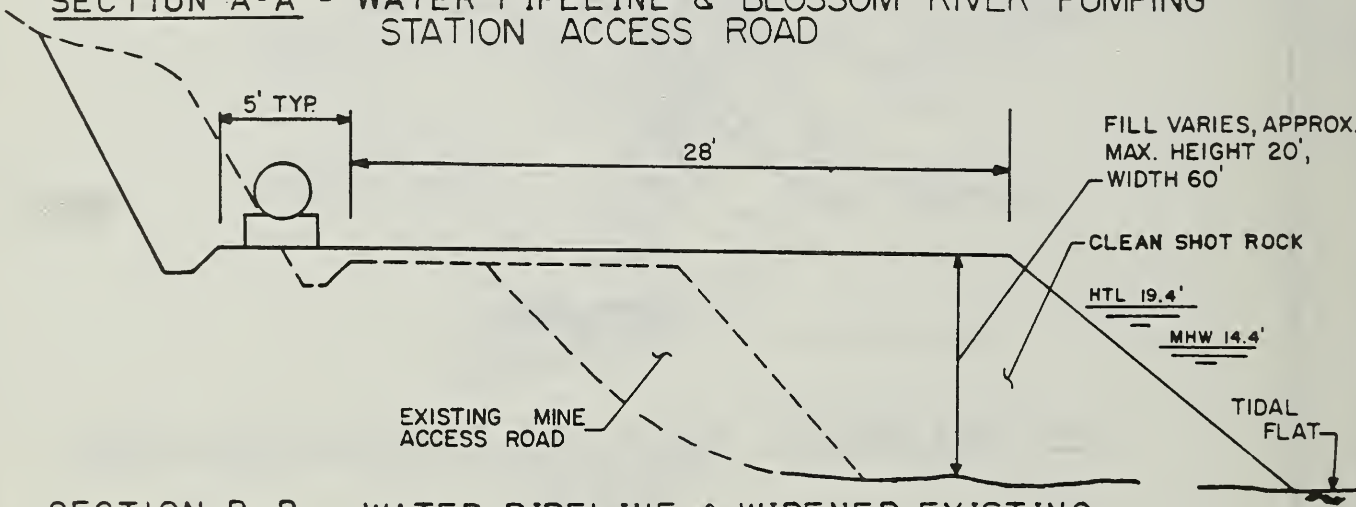
SECTION A

PROPOSED ACCESS ROAD STREAM CROSSING

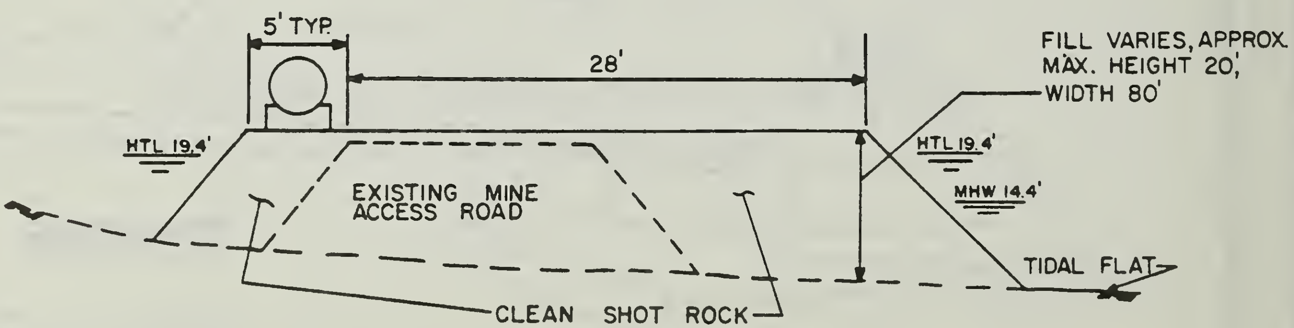
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND Smeaton Bay 5
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13,1987
SHEET 13 OF 33 DATE: JANUARY 21,1985



SECTION A-A - WATER PIPELINE & BLOSSOM RIVER PUMPING STATION ACCESS ROAD



SECTION B-B - WATER PIPELINE & WIDENED EXISTING MINE ACCESS ROAD AT SHORELINE



SECTION C-C - WATER PIPELINE & WIDENED EXISTING MINE ACCESS ROAD IN TIDAL FLAT

NOTES:

1. SEE SHEET 11 FOR TYPICAL CULVERT DETAILS.
2. SEE SHEET 9 FOR LOCATION OF SECTIONS A-A, B-B, & C-C.

(ALL THREE SECTIONS NOT TO SCALE)

PROPOSED WATER SUPPLY SYSTEM
CONVEYANCE PIPELINE & ACCESS ROADS

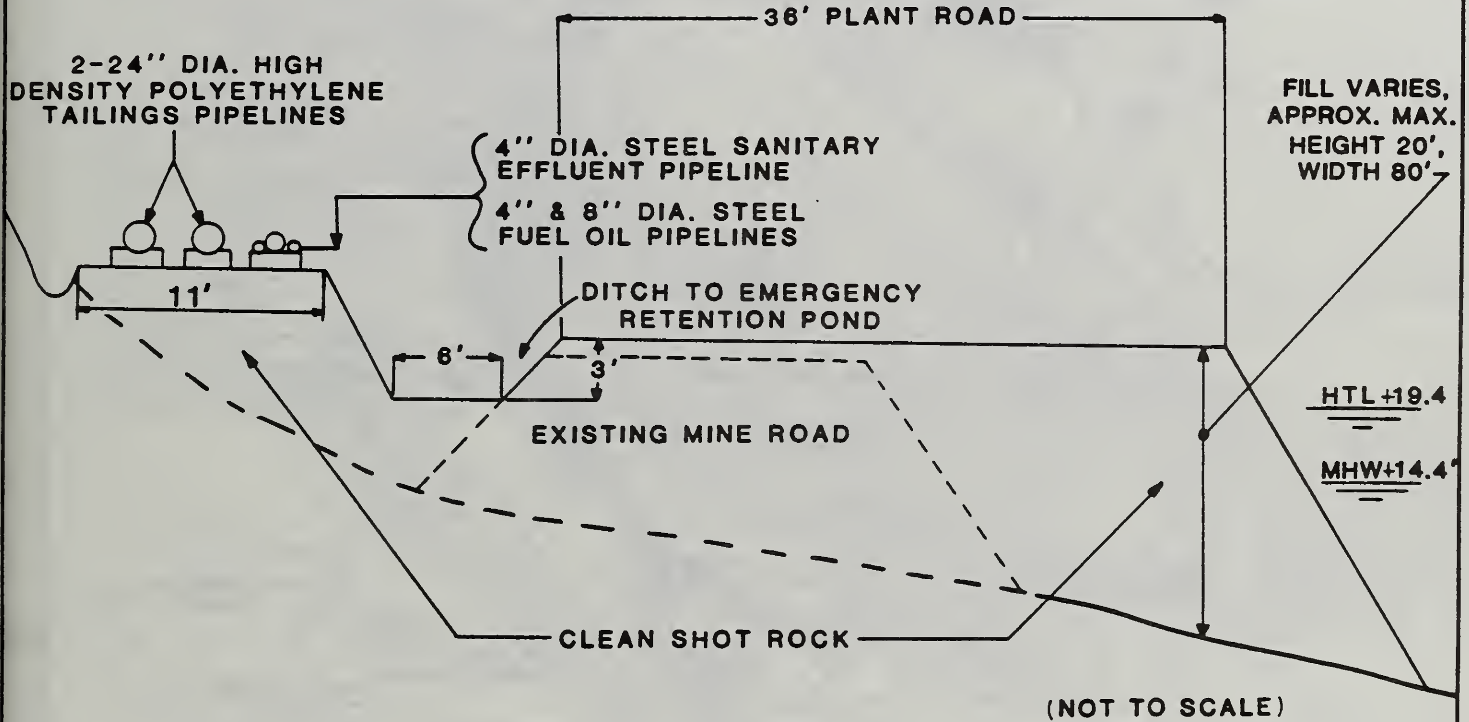
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND

Smeaton Bay 5

APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

Revd. NOVEMBER 13, 1987

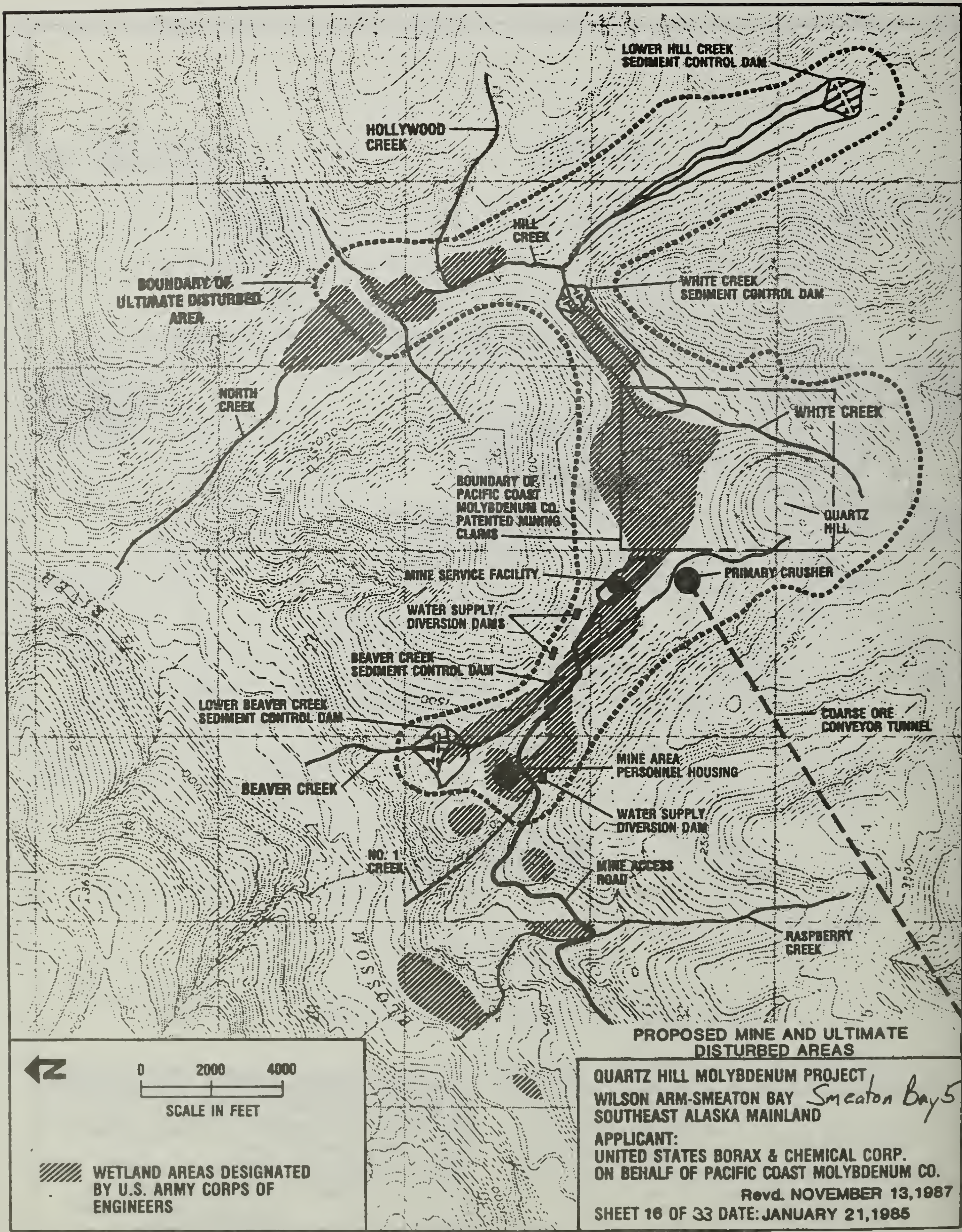
SHEET 14 OF 33 DATE: JANUARY 21, 1985

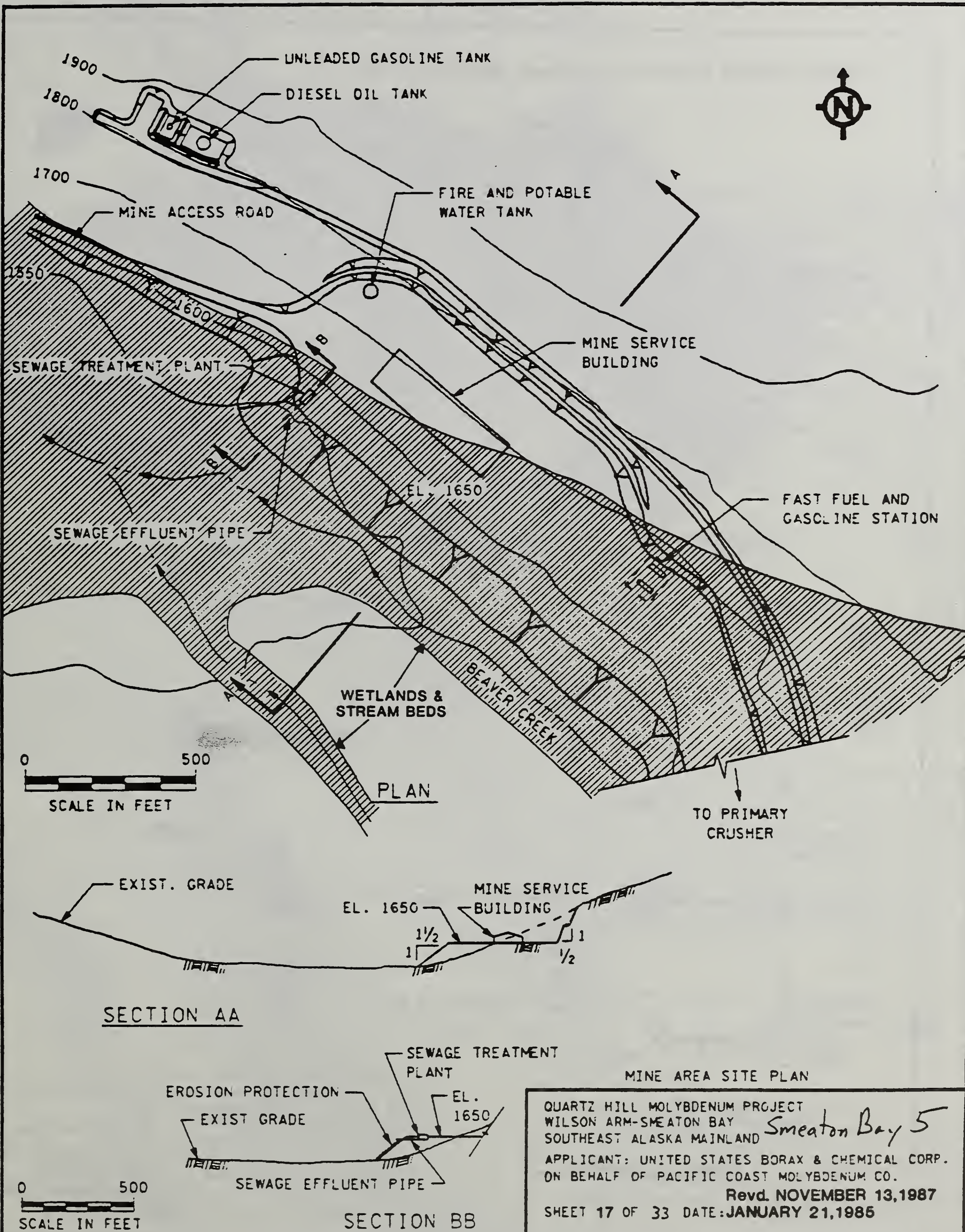


SECTION D-D
(SEE SHEET 9)

PLANT ROAD ALONG TIDEWATER

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND
Smeaton Bay 5
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13,1987
SHEET 15 OF 33 DATE: JANUARY 21,1985


LOWER HILL CREEK SEDIMENT CONTROL DAM
HOLLYWOOD CREEK
HILL CREEK
BOUNDARY OF ULTIMATE DISTURBED AREA
WHITE CREEK SEDIMENT CONTROL DAM
NORTH CREEK
WHITE CREEK
BOUNDARY OF PACIFIC COAST MOLYBDENUM CO. PATENTED MINING CLAIMS
QUARTZ HILL
MINE SERVICE FACILITY
PRIMARY CRUSHER
WATER SUPPLY DIVERSION DAMS
BEAVER CREEK SEDIMENT CONTROL DAM
LOWER BEAVER CREEK SEDIMENT CONTROL DAM
COARSE ORE CONVEYOR TUNNEL
BEAVER CREEK
MINE AREA PERSONNEL HOUSING
WATER SUPPLY DIVERSION DAM
NO. 1 CREEK
MINE ACCESS ROAD
RASPBERRY CREEK
0 2000 4000
SCALE IN FEET
WETLAND AREAS DESIGNATED BY U.S. ARMY CORPS OF ENGINEERS
PROPOSED MINE AND ULTIMATE DISTURBED AREAS
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY Smeaton Bay 5
SOUTHEAST ALASKA MAINLAND
APPLICANT:
UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13,1987
SHEET 16 OF 33 DATE: JANUARY 21,1985



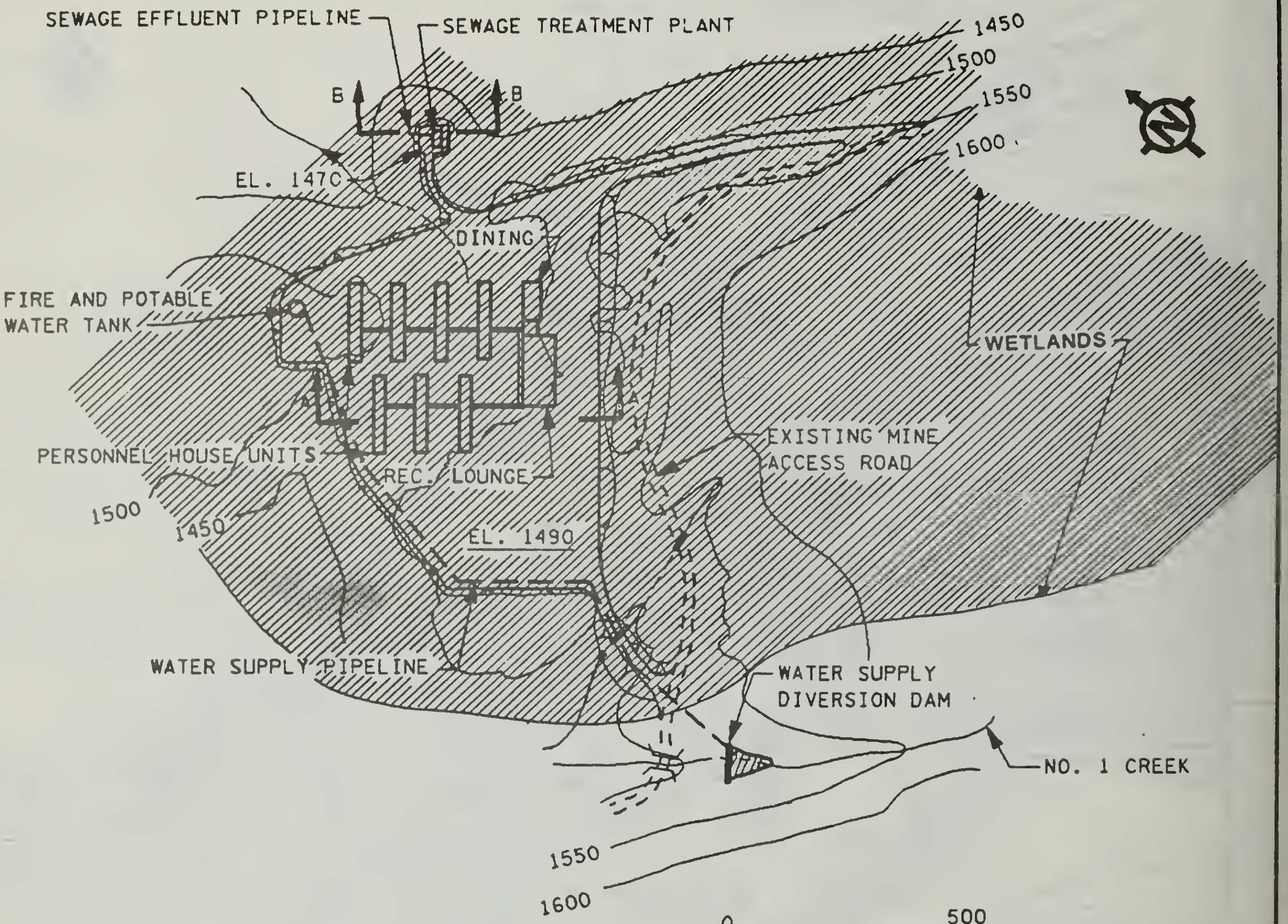
MINE AREA SITE PLAN

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND Smeaton Bay 5

APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

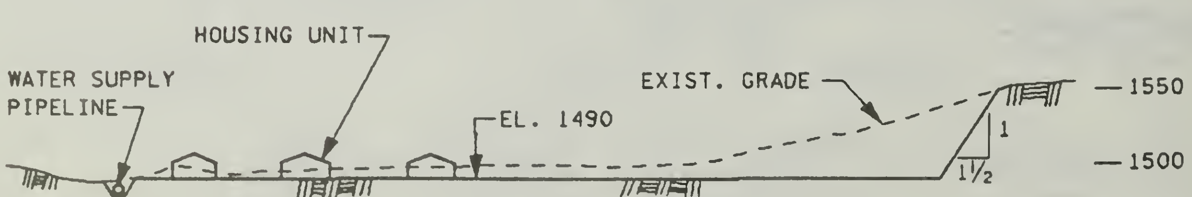
Revd. NOVEMBER 13,1987

SHEET 17 OF 33 DATE: JANUARY 21,1985

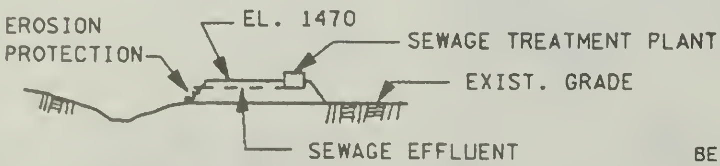


PLAN

0 500
SCALE IN FEET



SECTION AA



SECTION BB

0 200
SCALE IN FEET

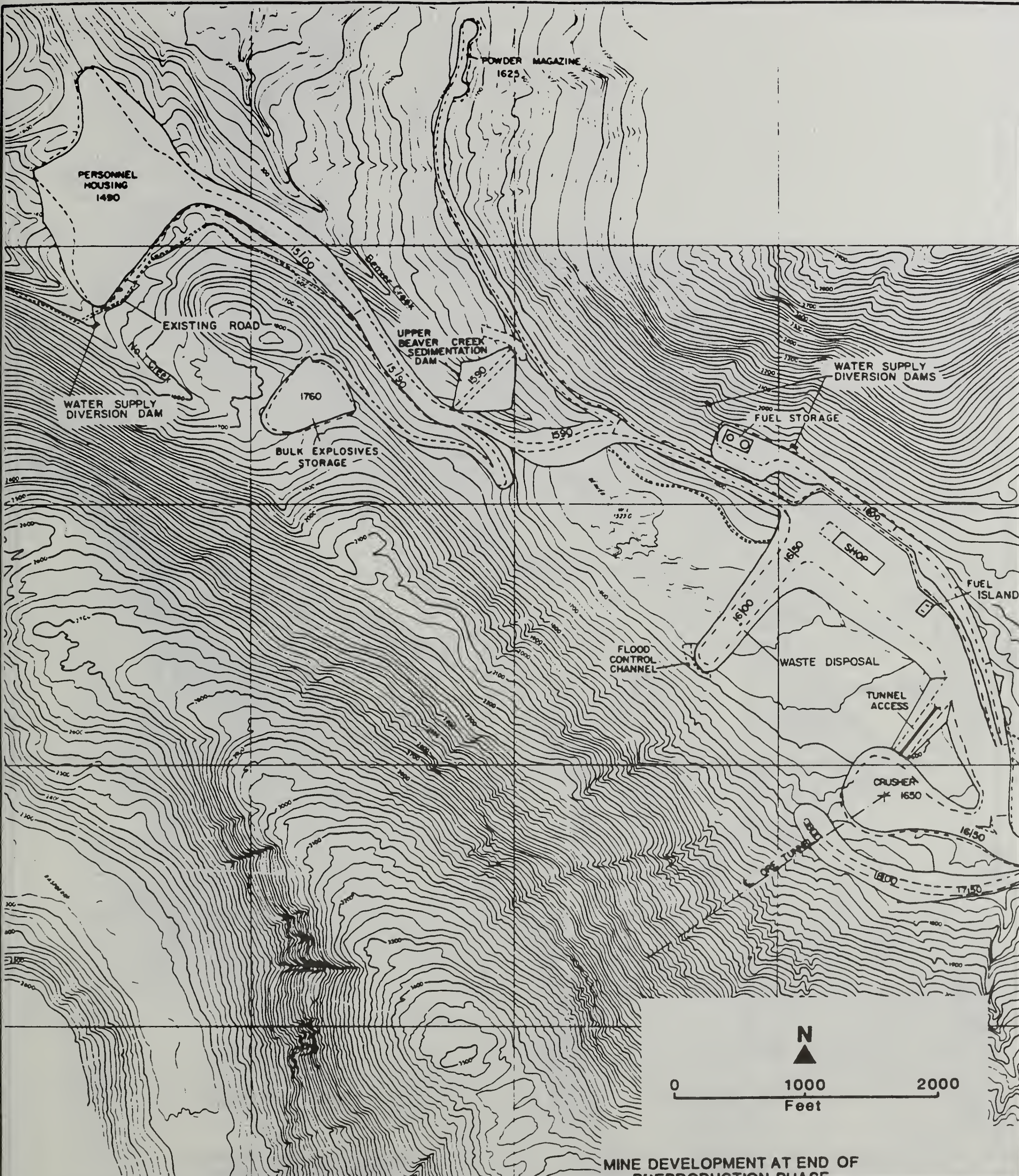
BEAVER CREEK PERSONNEL HOUSING

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND *Smeaton Bay 5*

APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

Revd. NOVEMBER 13,1987

SHEET 18 OF 33 DATE: **JANUARY 21,1985**



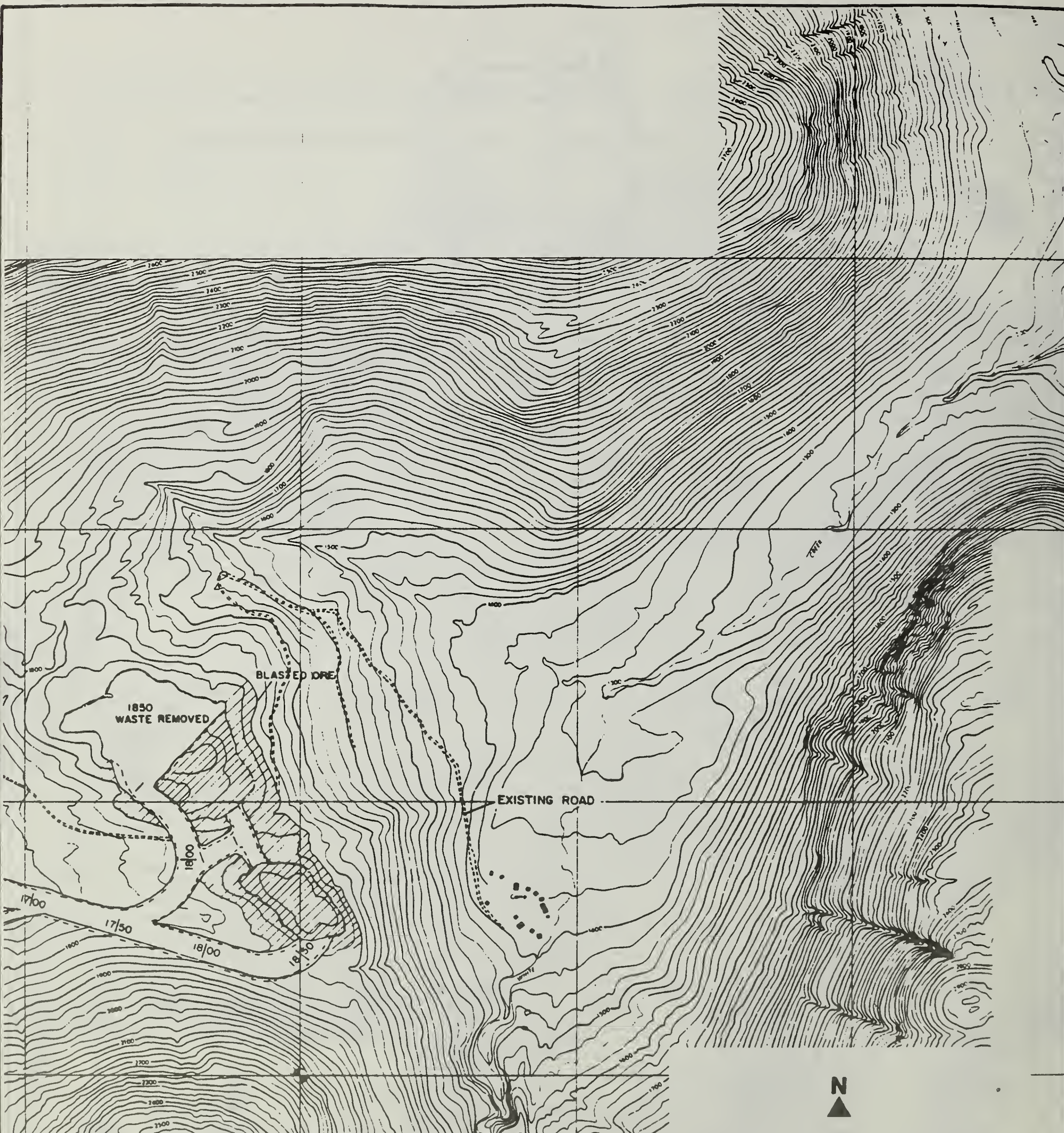
MINE DEVELOPMENT AT END OF PREPRODUCTION PHASE

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND

Smeaton Bay-5

APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

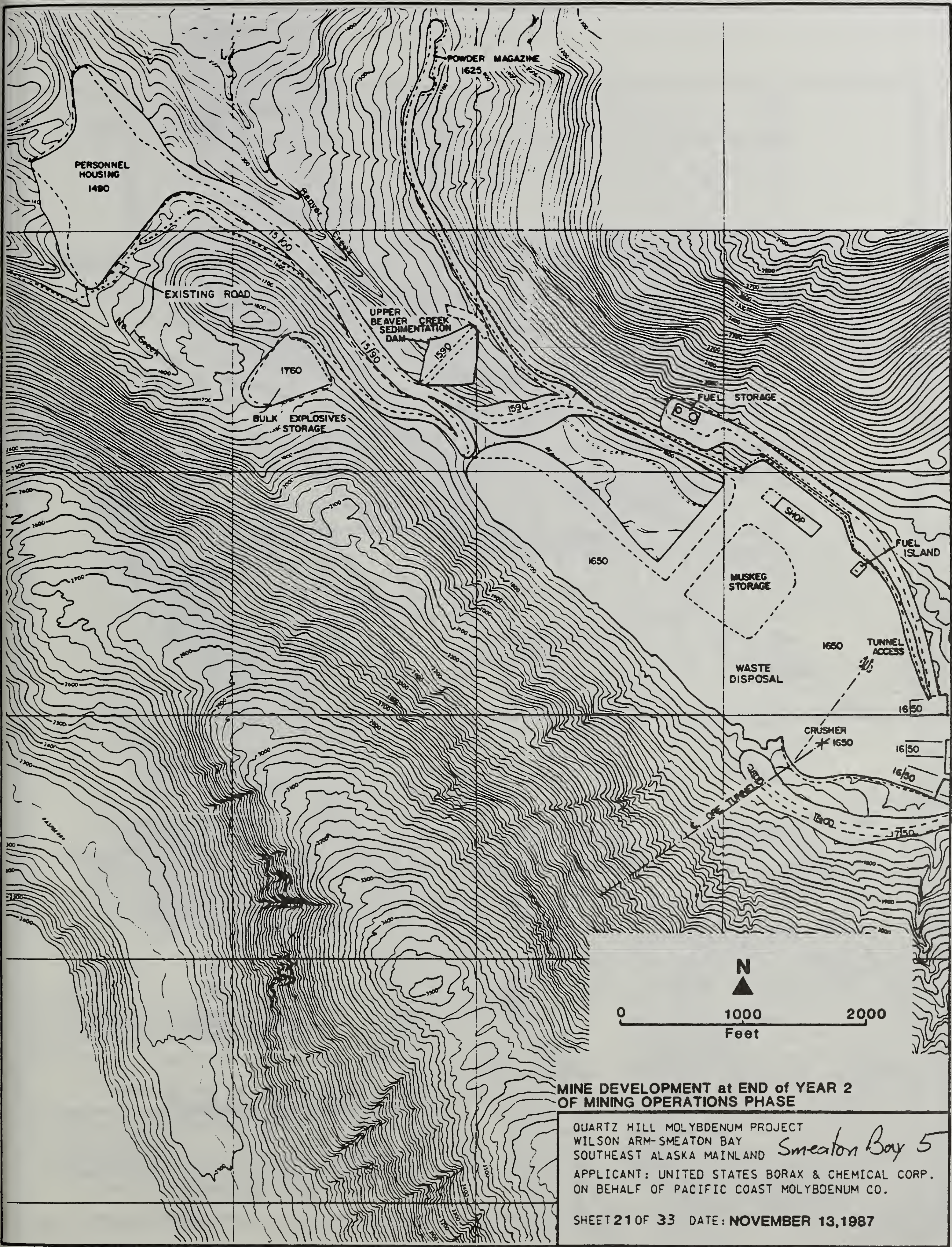
SHEET 19 OF 33 DATE: **NOVEMBER 13,1987**



MINE DEVELOPMENT AT END OF PREPRODUCTION PHASE

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND Smeaton Bay 5
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

SHEET 20 OF 33 DATE: NOVEMBER 13,1987



MINE DEVELOPMENT at END of YEAR 2 OF MINING OPERATIONS PHASE

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND

Smeaton Bay 5

APPLICANT: UNITED STATES BORAX & CHEMICAL CORP. ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

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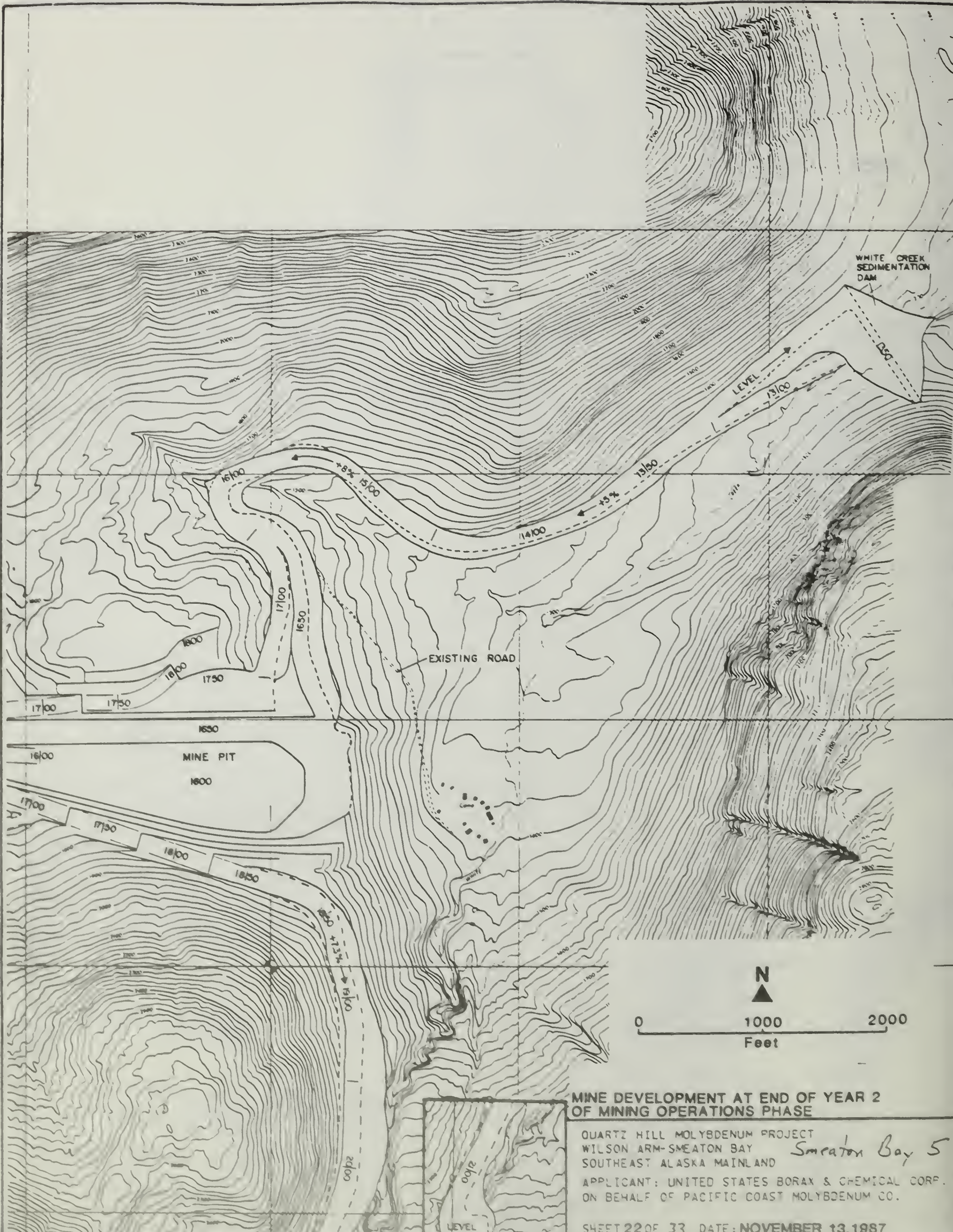
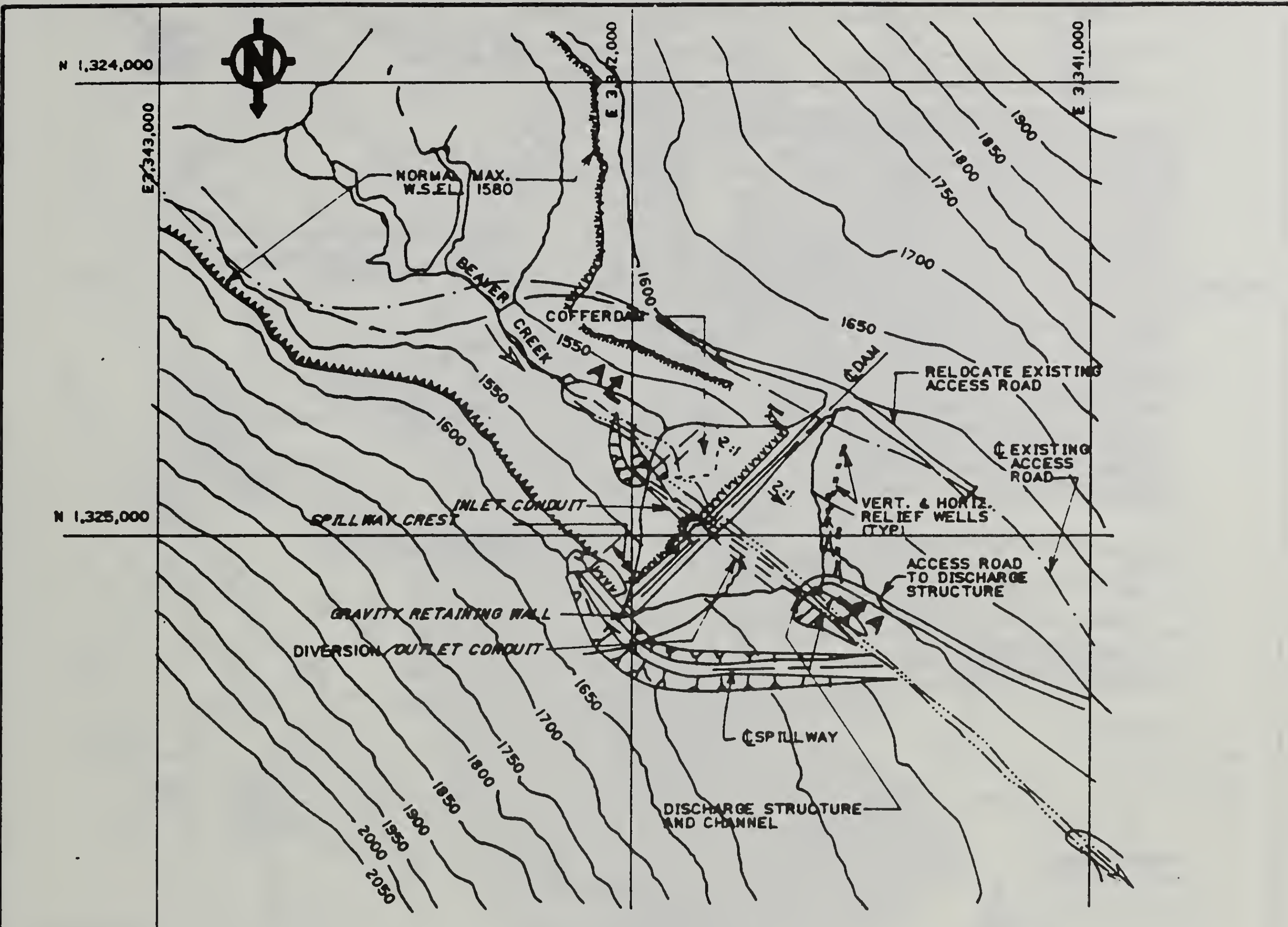
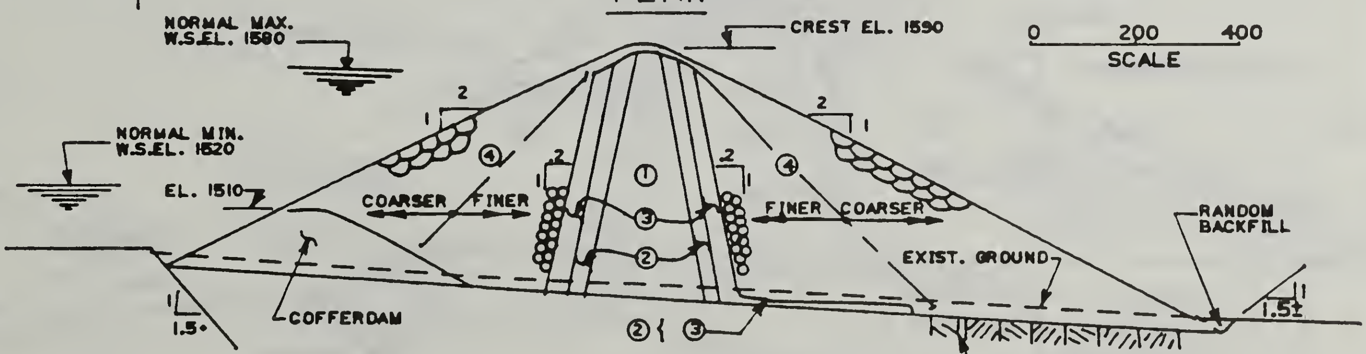
Match Line Sheet 21



See Inset To Right



PLAN



ZONES

① CORE - SELECT GLACIAL TILL
② TRANSITION - PROCESSED SAND
③ TRANSITION - PROCESSED GRAVEL
④ SHELLS - SELECT ROCK FROM MINE WASTE

SECTION A-A

0 50 100
SCALE

NOTE: ALL WITHIN WETLANDS

UPPER BEAVER CREEK SEDIMENT CONTROL DAM

PROPOSED SEDIMENT CONTROL DAMS

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY — Smeaton Bay 5
SOUTHEAST ALASKA MAINLAND
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13, 1987
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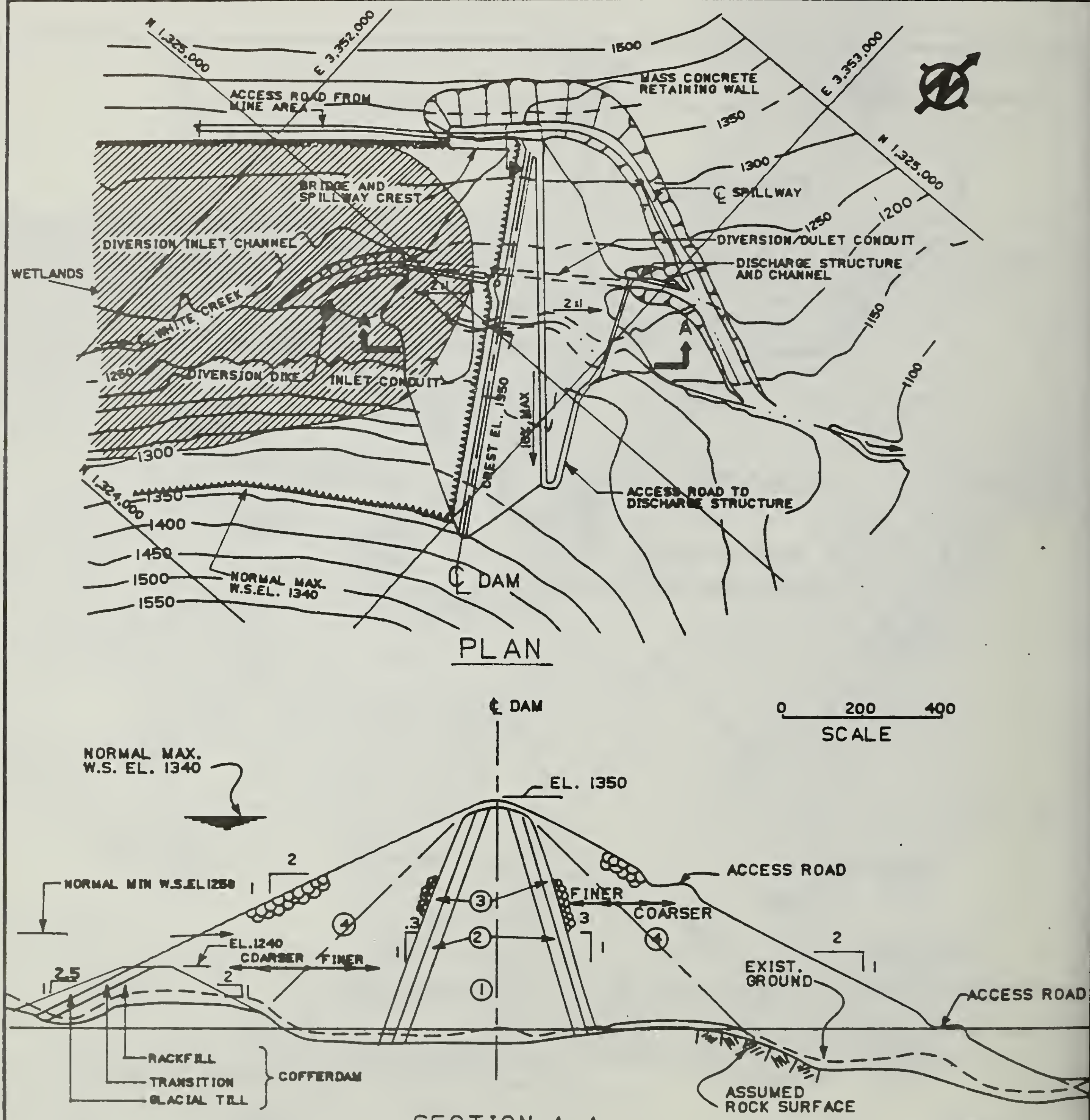

ZONES

1. CORE - SELECT GLACIAL TILL
2. TRANSITION - PROCESSED SAND
3. TRANSITION - PROCESSED GRAVEL
4. SHELLS - SELECT ROCK FROM MINE WASTE

WHITE CREEK SEDIMENT CONTROL DAM

PROPOSED SEDIMENT CONTROL DAMS

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY *Smeaton Bay 5*
SOUTHEAST ALASKA MAINLAND
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13,1987
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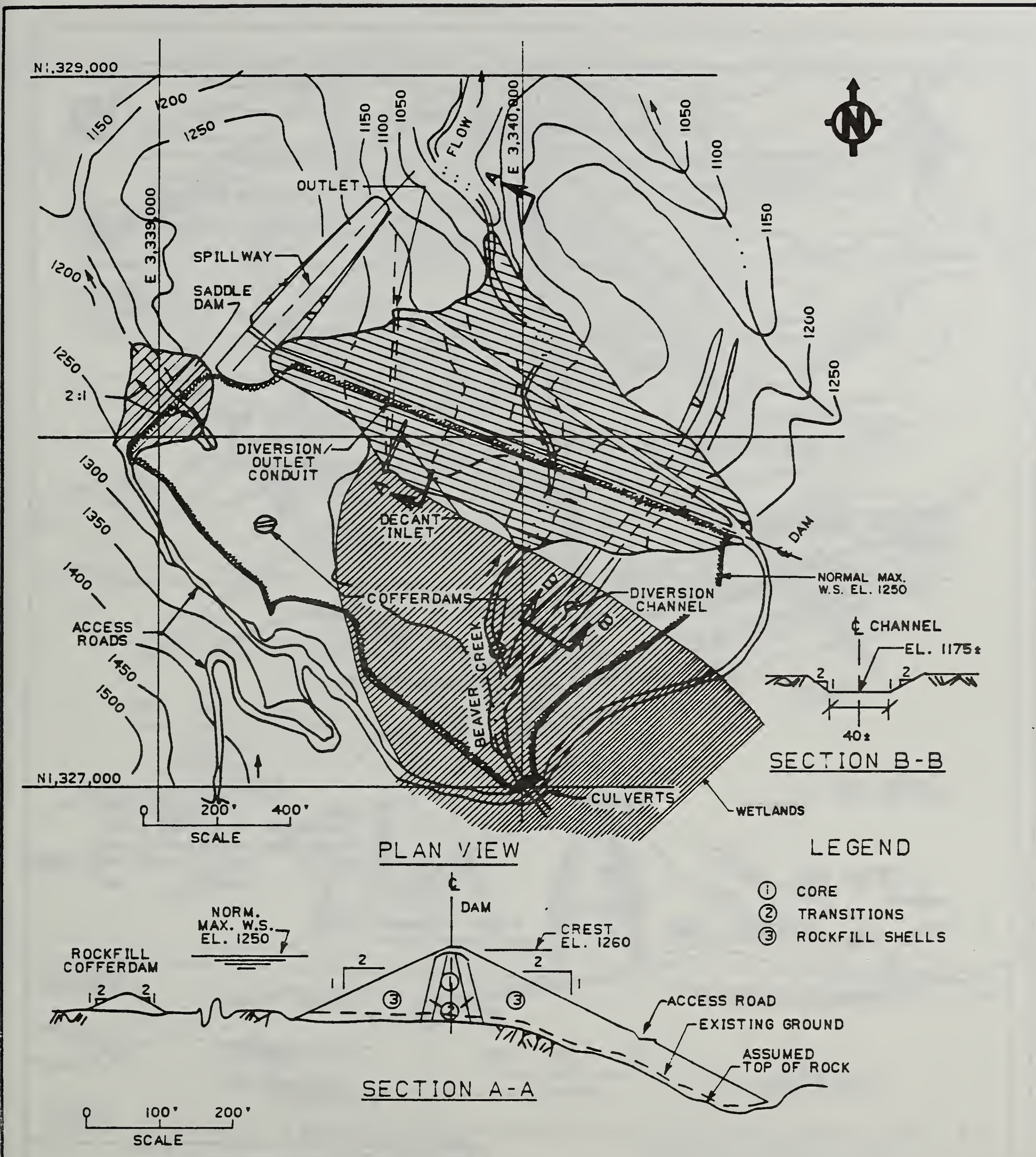
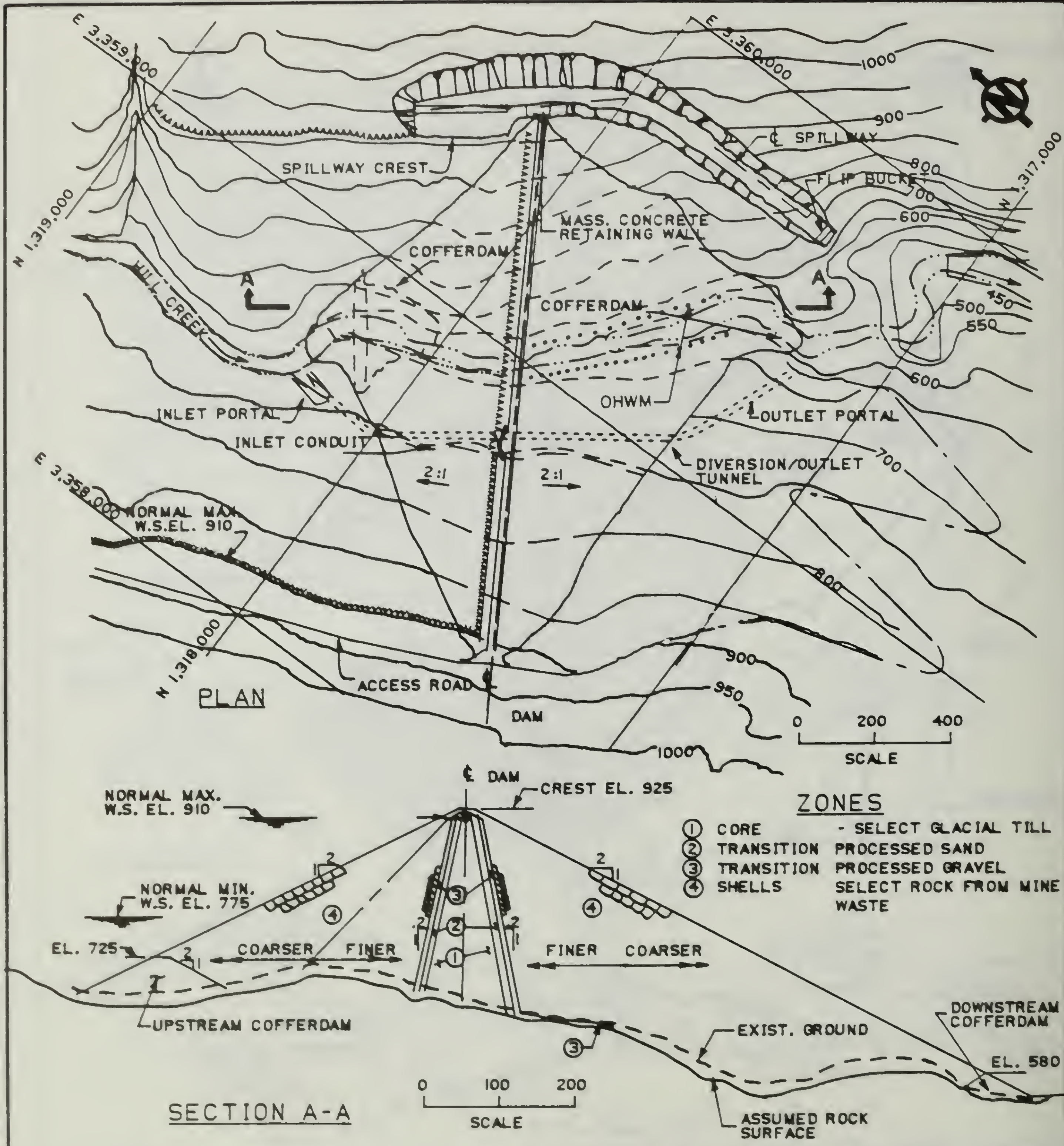


PROPOSED SEDIMENT CONTROL DAMS

LOWER BEAVER CREEK

SEDIMENT CONTROL DAM

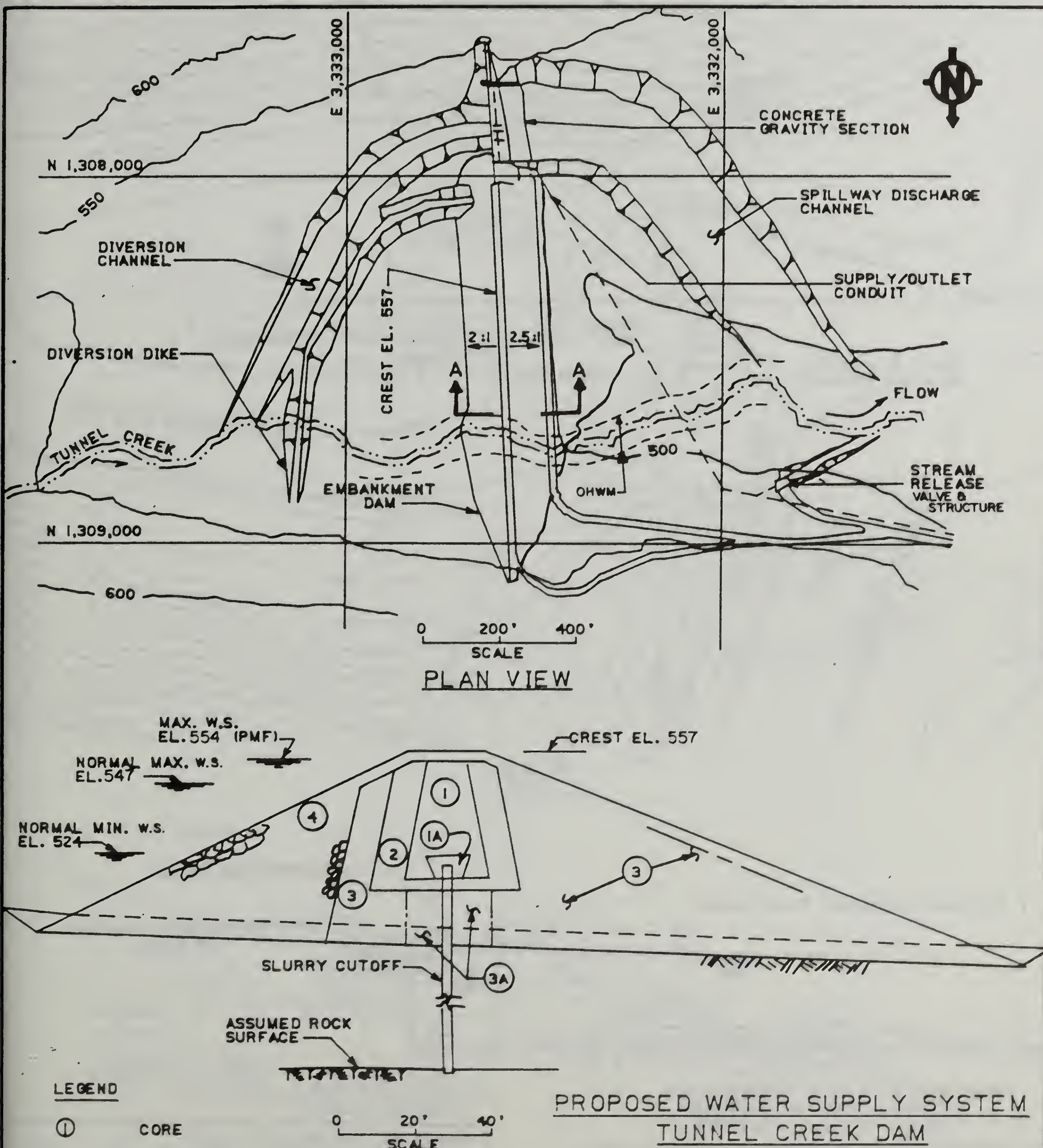
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY *Smeaton Bay 5*
SOUTHEAST ALASKA MAINLAND
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13, 1987
SHEET 25 OF 33 DATE: JANUARY 21, 1985



PROPOSED SEDIMENT CONTROL DAMS

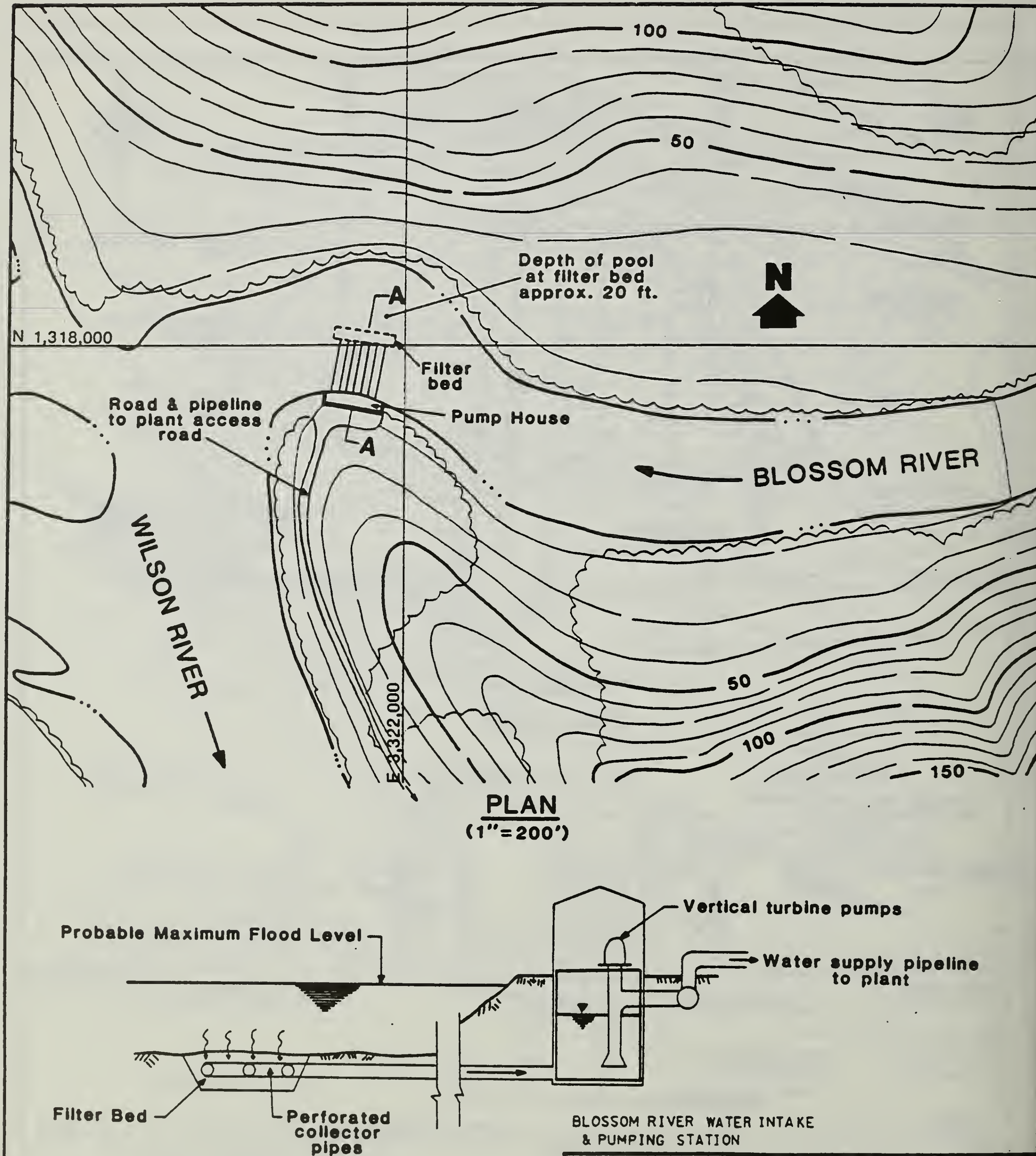
HILL CREEK SEDIMENT CONTROL DAM

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY *Smeaton Bay 5*
SOUTHEAST ALASKA MAINLAND
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13, 1987
SHEET 26 OF 33 DATE: JANUARY 21, 1985



PROPOSED WATER SUPPLY SYSTEM
TUNNEL CREEK DAM

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY Smeaton Bay 5
SOUTHEAST ALASKA MAINLAND
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13, 1987
SHEET 27 OF 33 DATE: JANUARY 21, 1985



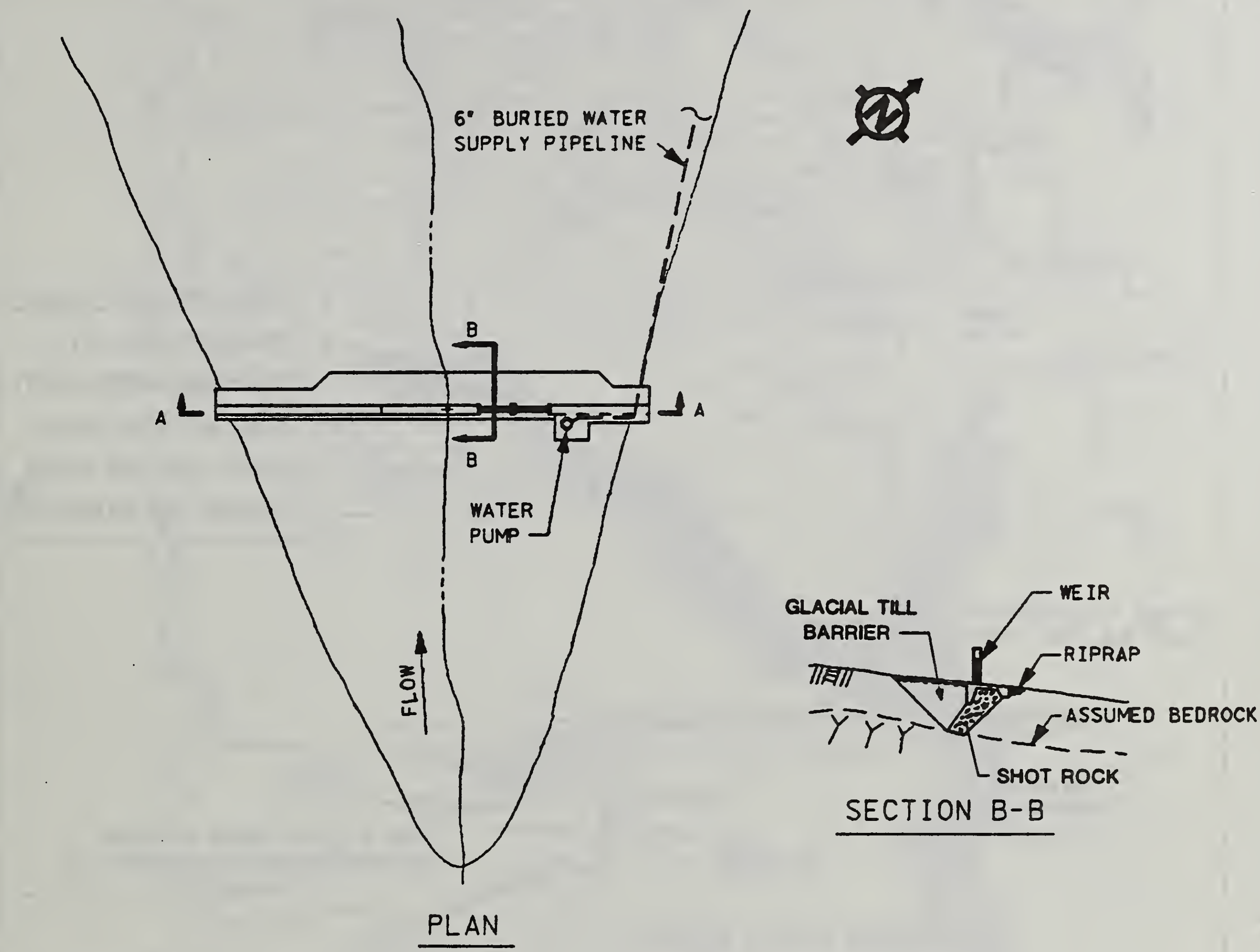
BLOSSOM RIVER WATER INTAKE
& PUMPING STATION

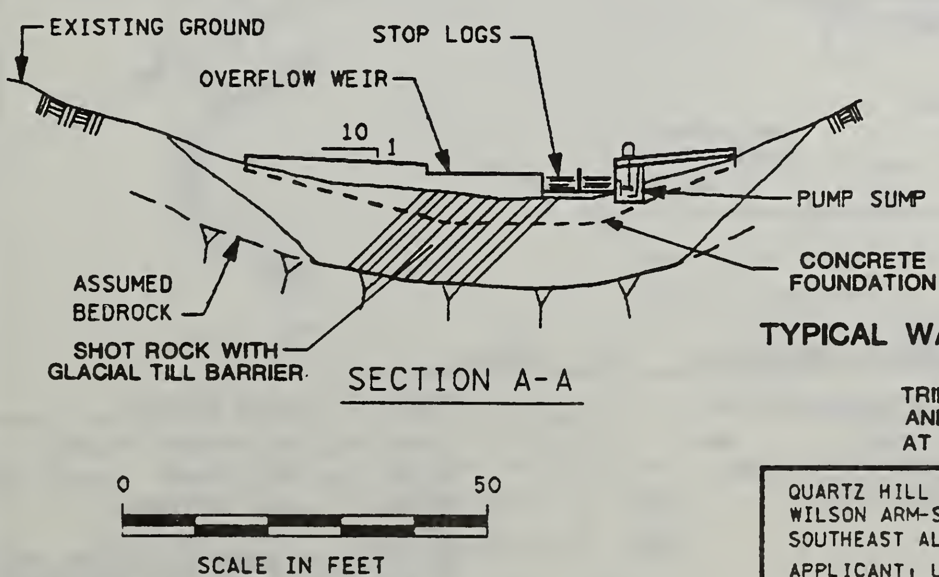
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND

Smeaton Bay 5

APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

SHEET 28 OF 33 DATE: NOVEMBER 13,1987





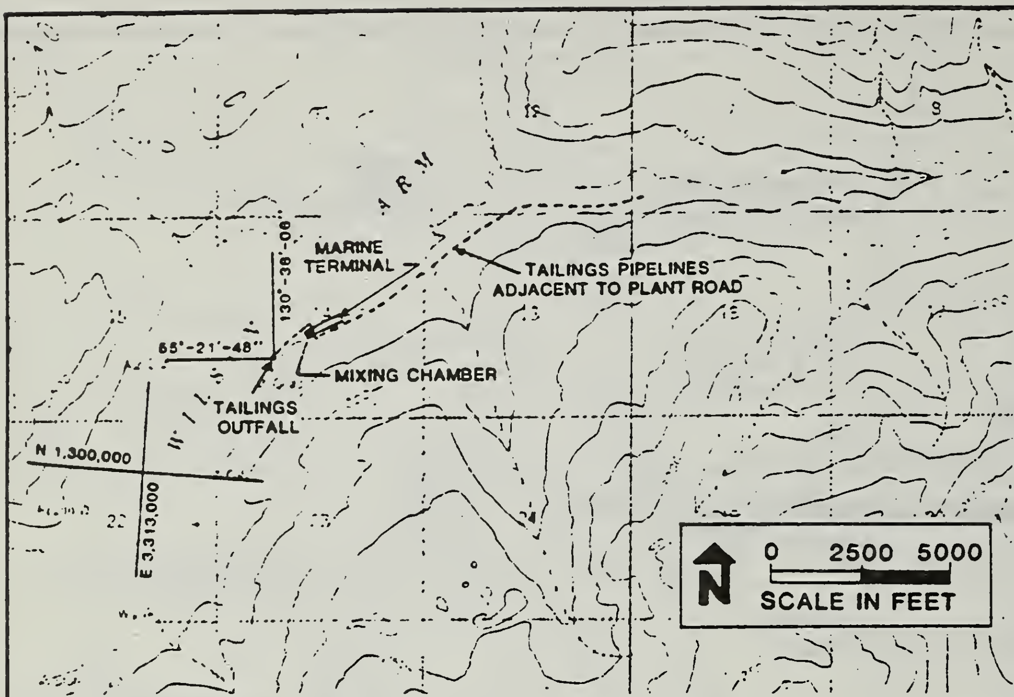
TYPICAL WATER SUPPLY DIVERSION DAM

TYPICAL FOR #1 CREEK,
TRIBUTARY AT MARINE TERMINAL
AND 2 WATER SUPPLY SOURCES
AT THE MINE SERVICE FACILITIES

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND Smeaton Bay 5

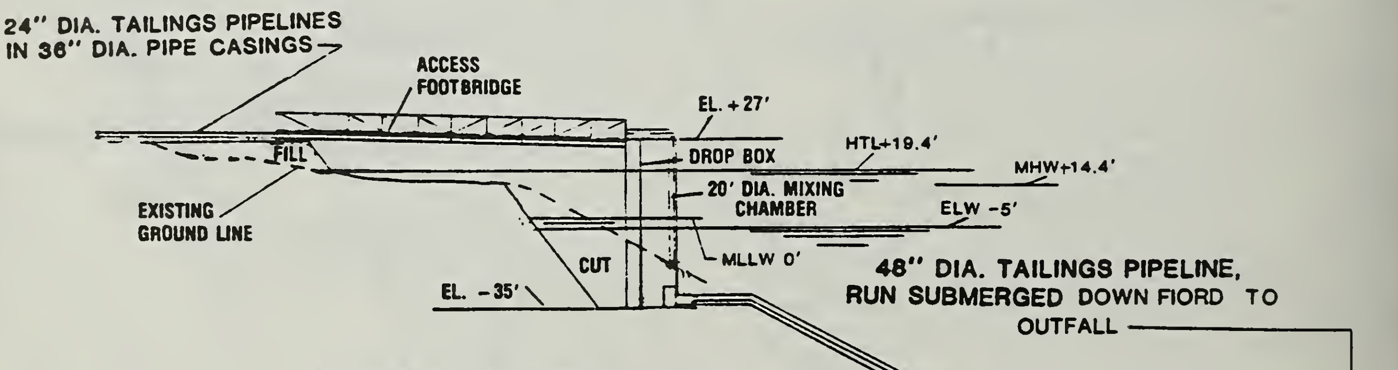
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

Revd. NOVEMBER 13,1987
SHEET 29 OF 33 DATE: JANUARY 21,1985



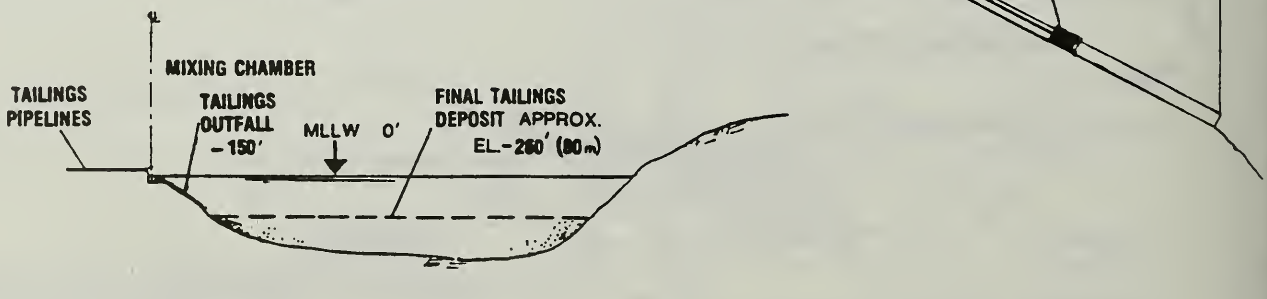
WILSON ARM TIDAL DATA

HIGH TIDE LINE (HTL)	+19.4'
MEAN HIGH WATER (MHW)	+14.4'
MEAN SEA LEVEL (MSL)	+ 8.0'
MEAN LOWER LOW WATER (MLLW)	0.0'
EXTREME LOW WATER (ELW)	−5.0'



TAILINGS OUTFALL DETAIL

0 50 100
SCALE IN FEET



PROFILE OF TAILINGS OUTFALL

0 1000 2000
SCALE IN FEET

PROPOSED TAILINGS OUTFALL

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY Smeaton Bay 5
SOUTHEAST ALASKA MAINLAND
APPLICANT:
UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. NOVEMBER 13,1987
SHEET 30 OF 33 DATE: JANUARY 21,1985

Legend

Tailings Deposition

End Year 2

End Year 55

Sill

N

0 1 2

Miles

WILSON ARM/SMEATON BAY

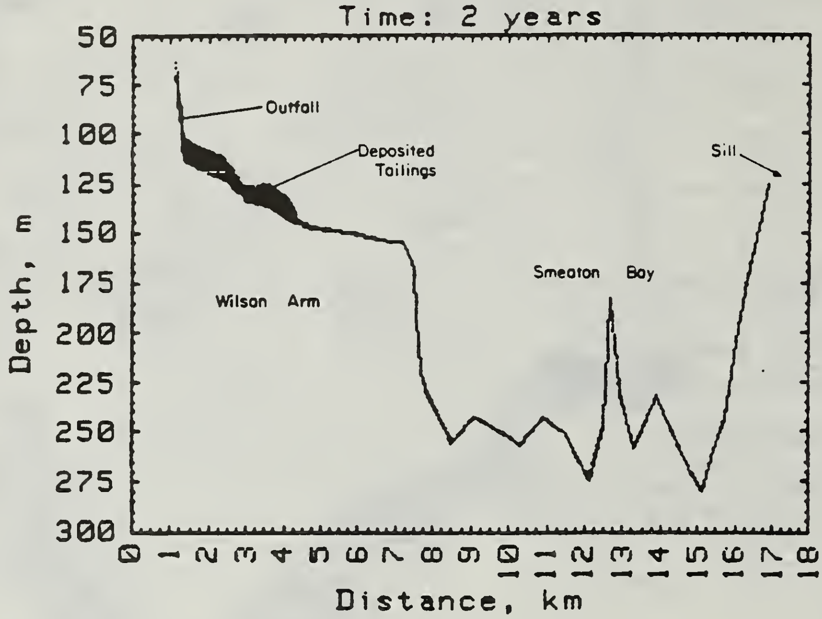
QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND

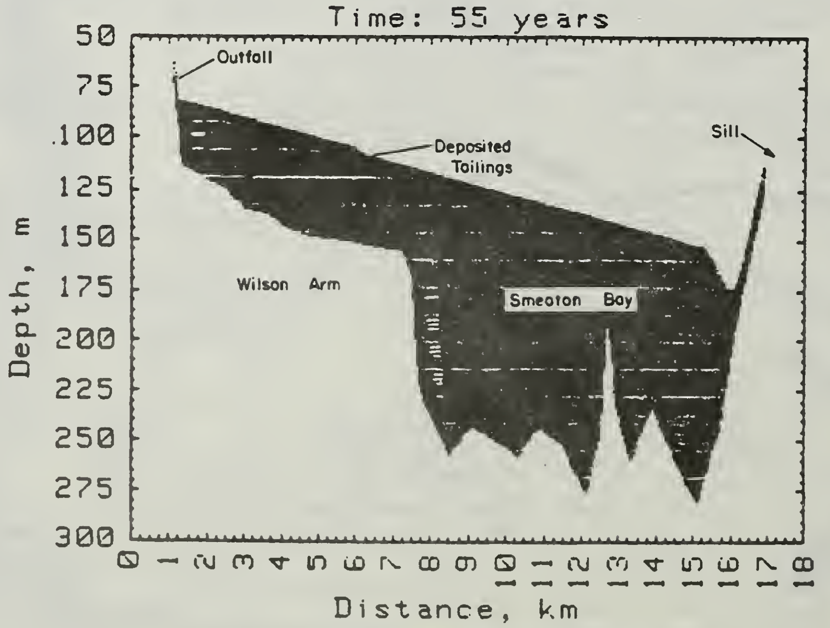
Smeaton Bay 5

APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

Revd. JUNE 17,1988

SHEET 31 OF 33 DATE: NOVEMBER 13,1987





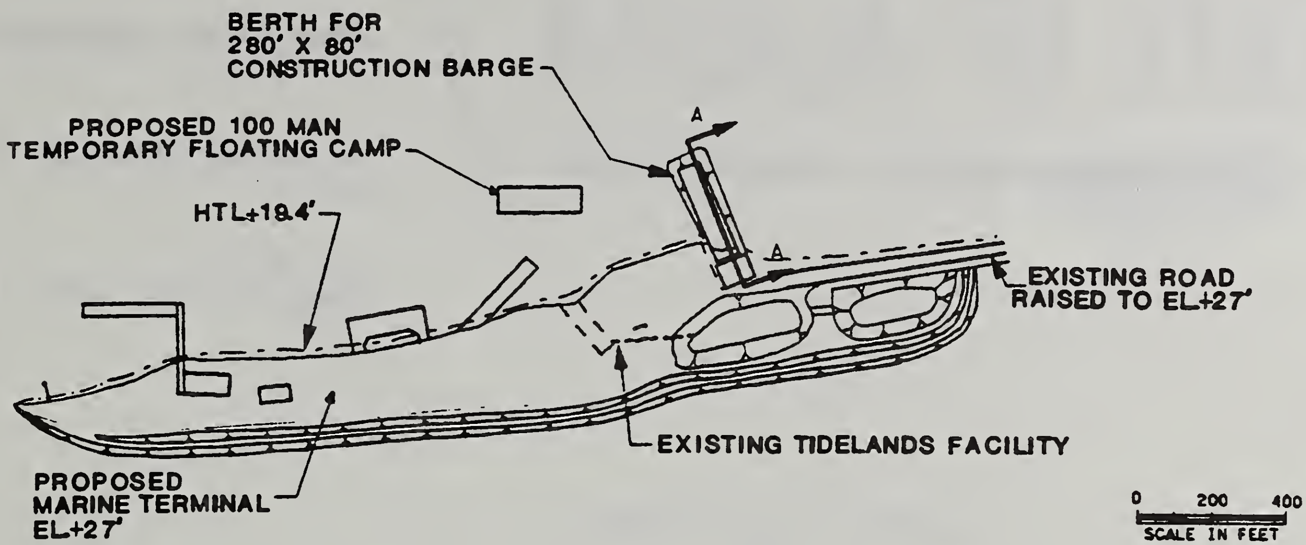
CROSS SECTIONS OF WILSON ARM/ SMEATON BAY SHOWING DEPOSITED TAILINGS

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND

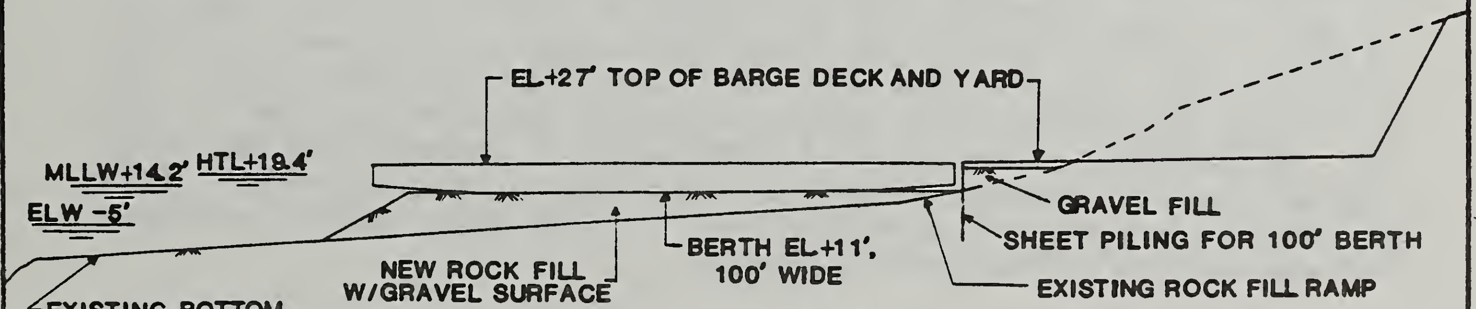
Smeaton Bay 5

APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.

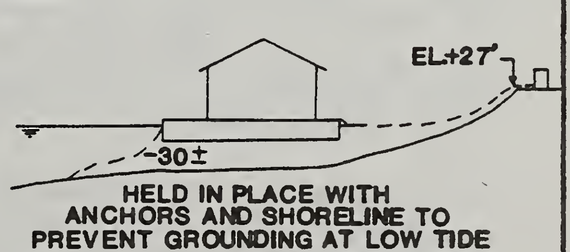
SHEET 32 OF 33 DATE: **NOVEMBER 13,1987**



PLAN VIEW OF WILSON ARM
FLOATING CAMP



CONSTRUCTION BARGE IN POSITION
SECTION A-A
(SCALE 1''=110')



HELD IN PLACE WITH
ANCHORS AND SHORELINE TO
PREVENT GROUNDING AT LOW TIDE

FLOATING CAMP
TYPICAL DETAILS
(NOT TO SCALE)

PROPOSED CONSTRUCTION SUPPORT FACILITIES

QUARTZ HILL MOLYBDENUM PROJECT
WILSON ARM-SMEATON BAY
SOUTHEAST ALASKA MAINLAND
Smeaton Bay 5
APPLICANT: UNITED STATES BORAX & CHEMICAL CORP.
ON BEHALF OF PACIFIC COAST MOLYBDENUM CO.
Revd. JUNE 17,1988
SHEET 33 OF 33 DATE: JANUARY 21,1985

STATE OF ALASKA

DEPT. OF ENVIRONMENTAL CONSERVATION

STEVE COWPER, GOVERNOR

Telephone: (907) 465-2600
Address:

P.O. Box 0
Juneau, AK 99811-1800

NOTICE OF APPLICATION
FOR
STATE WATER QUALITY CERTIFICATION

Any applicant for a Federal license or permit to conduct any activity which may result in any discharge into the navigable waters must first apply for and obtain certification from the Alaska Department of Environmental Conservation that any such discharge will comply with the Clean Water Act of 1977 (PL 95-217), the Alaska Water Quality Standards and other applicable State laws. By Agreement between the U.S. Army Corps of Engineers and the Alaska Department of Environmental Conservation application for a Department of the Army Permit may also serve as application for State Water Quality Certification when such certification is necessary.

Notice is hereby given that the application for a Department of the Army Permit described in the Corps of Engineers Public Notice No. 2-840015 also serves as application for State Water Quality Certification from the Alaska Department of Environmental Conservation, as provided in Section 401 of the Clean Water Act of 1977 (PL 95-217).

The Department will review the proposed activity to insure that any discharge to waters of the United States resulting from the referenced project will comply with the Clean Water Act of 1977 (PL 95-217) the Alaska Water Quality Standards and other applicable State laws.

Any person desiring to comment on the water quality impacts of the proposed project may do so by writing to:

Alaska Department of Environmental Conservation
Northern Regional Office
P.O. Box 1601
Fairbanks, Alaska 99701
Telephone: 452-1714

within 30 days of publication of this notice.

Attachment 2

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